

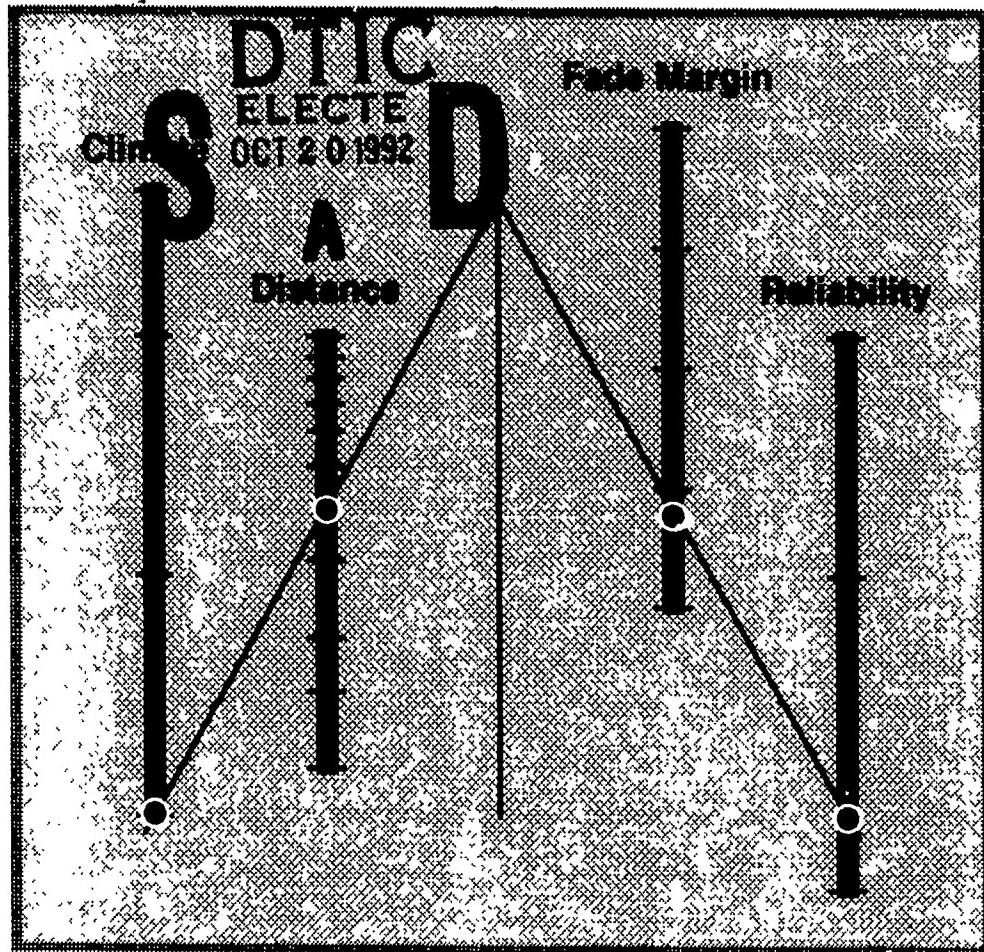
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Tactical Line-of-Sight Path Reliability: Improved MSE System Procedures

Technical Report
April 1992



**U.S. Army Communications-Electronics Command
Command, Control and Communications Systems Directorate
Fort Monmouth, New Jersey**

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**Research and Development Technical Report
CECOM-TR-92-1**

**Tactical Line-of-Sight Path Reliability:
Improved MSE System Procedures**

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ABSTRACT

Mobile Subscriber Equipment (MSE) provides digital voice, data, and packet-switched tactical communications for Army corps and division areas of coverage deployed anywhere in the world. Line-of-sight (LOS) links in MSE must operate satisfactorily in all climates and terrains; however, difficult propagation environments (e.g., that encountered in Southwest Asia) can diminish link reliability. This report describes enhancements to MSE operating procedures to address this problem. The enhanced procedures call for the user to specify the propagation reliability desired on a link, e.g., 99.9 percent. The corresponding required margin between the average received signal strength and that required for 10^{-5} bit-error-rate operation is then calculated as a function of link parameters such as path length and climate. The margin achieved during link initialization is measured, reported, and compared to the required margin as the basis for link acceptance. Also, since propagation-caused problems can not be cured by the current practice of replacing equipment, enhanced troubleshooting procedures are described. MSE radio equipment has the built-in capability to support these enhanced operating procedures and operate satisfactorily in all climates and terrains.

Although this report utilizes the MSE framework and terminology, the methodology and recommendations are applicable to any LOS digital radio system.

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EXECUTIVE SUMMARY

This report focuses on improvements in network planning and operating procedures for Mobile Subscriber Equipment (MSE) radio needed to achieve line-of-sight (LOS) links that operate reliably in all climates and terrains. Experience with LOS links in Southwest Asia has shown that fading (time-varying atmospheric reduction of received signal strength [RSS]) can significantly reduce link propagation reliability. Link propagation reliability is also affected by the noise power at the radio receiver input; the higher the noise power, the more susceptible the LOS link is to fading. The enhanced procedures described here improve propagation reliability by considering fading and radio frequency interference (RFI) as well as their possible misidentification as equipment failures. The enhanced procedures address three areas: link planning, link initialization/acceptance, and link operation/troubleshooting. MSE radio equipment has the built-in capability to support these enhanced operating procedures and operate satisfactorily in all climates and terrains.

Link planning enhancements call for the user to specify a desired link propagation reliability, e.g., 99.9 percent. For a specific value of propagation reliability, there is a corresponding value for the normal RSS, which is larger than the signal strength at which the error rate becomes unacceptable (10^{-5} is a commercially acceptable value for data transmission). The difference between these two signal strengths is the required fade margin (RFM) for the link. The RFM is calculated from the link application parameters: path length, frequency, climate, and terrain. A nomogram is provided to enable the calculation. A minimum RFM of 8 dB is recommended as a safety margin to allow for ever-present fluctuations in RSS noise level. The old link planning procedure does not provide a means for the user to select a desired reliability

value. It also has a fixed fade margin independent of link length and climate. The enhanced link planning procedure provides a method to achieve a user-specified propagation reliability by establishing required fade margin values for each application and any environment. In the future, this manual method will be replaced by an automatic network planning capability.

Link initialization/acceptance procedure enhancements call for measurement of the achieved link margin (ALM) during initialization of the link. The acceptance of a link under the new procedures is based on a comparison of the ALM to the RFM (must have $ALM \geq RFM$) or on the adequacy of the reliability that corresponds to ALM. Meeting the fade margin requirements may require LOS operators to use either high transmitter power or antenna heights above tree line, or both, during initialization. The power/height may be decreased during operation when fading is absent but should be at their initialization values when fading is expected or present. The new link initialization/acceptance procedures provide assurance that the usefulness of the link is not compromised because of initialization for a reliability lower than that planned at the MSE System Control Center (SCC). The old link initialization/acceptance procedure typically accepted the link if the BER was measurable, i.e., 10^{-5} . This is unsatisfactory because the corresponding fade margin is negligible, which means that the link has been initialized with no margin for fluctuations in RSS noise level.

Link operation/troubleshooting procedure enhancements are intended to reduce misidentification of problems. Current procedures to recognize and identify trouble are triggered by radio and switch alarms. The alarms are not accurate indicators of equipment failure because fading or RFI can trigger alarms when there is no equipment problem. In such cases, troubles can not be cured by replacing equipment. The new procedures help the opera-

tors properly identify the actual trouble source. When troubleshooting, equipment should not be changed out unless it is unequivocally identified as the trouble source. If there is any uncertainty, fading and RFI are to be eliminated as likely causes before any equipment is replaced. The Node Center Switch (NCS) operator directing the troubleshooting should interrogate alarm information on all links connected to the NCS, weather information (likelihood of fading), and known fade margin information (from records obtained during the initialization phase) when troubleshooting. For example, fading can intermittently affect more than one link at a time. This trait will be helpful in making a fading trouble identification.

This report discusses the enhanced procedures in detail regarding link design, link initialization, and continued operation. The body of the report is targeted to command personnel; the appendixes are directed to system operators. The main body contains a description of the equipment's performance related to the fading and RFI environments. This is followed by a discussion of the enhanced procedures organized by work center: SCC, NCS, and LOS radio.

Although this report utilizes the MSE framework and terminology, the methodology and recommendations are applicable to any LOS digital radio system.

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**TACTICAL LINE-OF-SIGHT PATH RELIABILITY:
IMPROVED MSE SYSTEM PROCEDURES**

1 INTRODUCTION

1.1 BACKGROUND

Experience with line-of-sight (LOS) links in Southwest Asia (SWA) has shown that fading (time-varying atmospheric reduction of received signal strength [RSS]) can significantly reduce link reliability. This document describes enhanced procedures that will allow LOS links in Mobile Subscriber Equipment (MSE) to operate more reliably in the presence of fading. Link reliability is also affected by the noise power at the radio receiver input; the higher the noise power, the greater the impact of fading. Therefore, the enhanced procedures improve reliability by considering fading and radio-frequency interference (RFI), and their possible misidentification as equipment failures. The enhanced procedures cover link planning, acceptance, initialization, and continued operation. The enhanced procedures are needed because current planning procedures, operational procedures, training, and lesson plans do not address time variations in the RSS due to fading or time variations in the noise levels due to interference.

1.2 OVERVIEW

The body of this document is targeted to MSE System Control Center (SCC) command personnel (S3); the appendixes are directed to system operators. The main body contains a description of the equipment's performance related to fading and RFI environments. This is followed by a discussion of the enhanced procedures organized by work function: link design, link initialization, and continued operations. The appendixes are organized by work center: SCC, Node Center Switch (NCS), and LOS. The appendixes are source material for technical manual updates.

I is assumed that the reader of this document is knowledgeable about the MSE system and its operation but may not be knowledgeable about either the time variations in the RSS due to fading or the time variations in the radio system noise level due to RFI.

The procedures presented in this document are for planning, installation, and continued operations of the MSE LOS assemblage, AN/TRC-190(V). The bit error rate (BER) sensitivity of digital radio equipment to variations in RSS near its operating threshold leads to a recommendation for a minimum fade margin of 8 dB (2 bars) for all radio installations. This and other fading-related considerations for these assemblages are covered in section 2.1. It should be noted that any margin engineered into an LOS link to counter fading will also improve performance in an interference-caused high-noise environment when there are no fading conditions. However, the available fade margin will be reduced in a high-noise environment.

The new capability for designing links in the presence of fading is based on a fading model developed for LOS tactical radio. This model is described in Technical Report CECOM-TR-91-3, "Tactical Line-of-Sight Radio Propagation Reliability,"¹ and is summarized in section 2.2. Use of the model generates the fade margin needed to meet the link reliability requirement for a wide range of climates for a given path length and radio frequency.

Nominal MSE LOS link planning provides propagation reliability of 90 percent or better. Critical single-thread links need propagation reliability of up to 99.9 percent, subject to equipment capability. For a required value of propagation reliability, there is a corresponding required value for the normal RSS, which is larger than the signal strength at which the error rate be-

1. Report available from: Commander, U.S. Army Communications-Electronics Command, ATTN: AMSEL-RD-C3-EM, Fort Monmouth, New Jersey 07703.

comes unacceptable (BER of 10^{-5} is a commercially acceptable value for data transmission). The difference of these two signal strengths, expressed in dB, is the required fade margin (RFM).

The new design procedures provide the means for establishing RFM values. The new procedures also require measurement of the achieved link margin (ALM) during initialization of the link. The acceptance of a link under the new procedures is based on a comparison of the ALM to the RFM (must have $ALM \geq RFM$) or on the adequacy of reliability that corresponds to ALM. This provides assurance that the usefulness of the link is not compromised because of initialization for a reliability lower than that planned at the SCC. The new link design procedures are summarized in section 3.1 and detailed for the SCC operator in Appendix A.

The required values of the RSS, signal-to-noise ratio (SNR), and BER for the initialization of the link are issued by the SCC operator to the NCS operator for use by the LOS operators.

Meeting these requirements may require the LOS operators to use either high transmitter power or antenna heights above tree line --or both--during initialization. The power/height can be decreased during operation when fading is absent. They should be at their initialization values when fading is expected or present. The measured results of the initialization tests by the LOS operators are to be provided to the NCS operator for evaluation and recording. The link initialization procedures are outlined in section 3.2 and described in detail in Appendix B for NCS operators and Appendix C for LOS operators.

Reliable operation of an LOS link requires procedures for trouble recognition, trouble source identification, and corrective action. Current procedures to recognize and identify trouble are triggered by alarms. The alarms are not accurate indicators of equipment failure because fading or RFI can trigger alarms when

there is no equipment problem. In such cases, troubles can not be cured by replacing equipment. Additional procedures to accommodate fading and high noise (interference) levels are outlined in section 3.3 and described in detail in Appendix B for NCS operators and in Appendix C for LOS operators.

The general steps in the new procedures are summarized in a flowchart in Figure 1-1. The flow requires interaction of the SCC operators, the NCS operators, and the LOS operators, which will be discussed in subsequent sections of this document.

Current operational procedures dictate that MSE LOS links be set up with the minimum RSS needed to obtain communications by placing the antennas at tree line to maximize technical and tactical camouflage. Some of the procedures to obtain high-reliability links outlined in this document call for increasing the antenna height/transmitted power of the LOS radio equipment. SCC command personnel and network planners must consider the trade-offs between link reliability versus the need for technical and tactical camouflage when planning and implementing LOS links.

2 EQUIPMENT PERFORMANCE AND ENVIRONMENT

The procedures in this document address performance of the radio equipment in the presence of fading and RFI. Technical information regarding equipment performance and environment is presented in this section.

2.1 EQUIPMENT PERFORMANCE

The AN/GRC-226(V) radio utilized on LOS links in MSE operates in Band I (225-400 MHz) and Band III (1350-1850 MHz). This report will use the term ultra-high-frequency (UHF) to refer to both Band I and Band III frequencies.

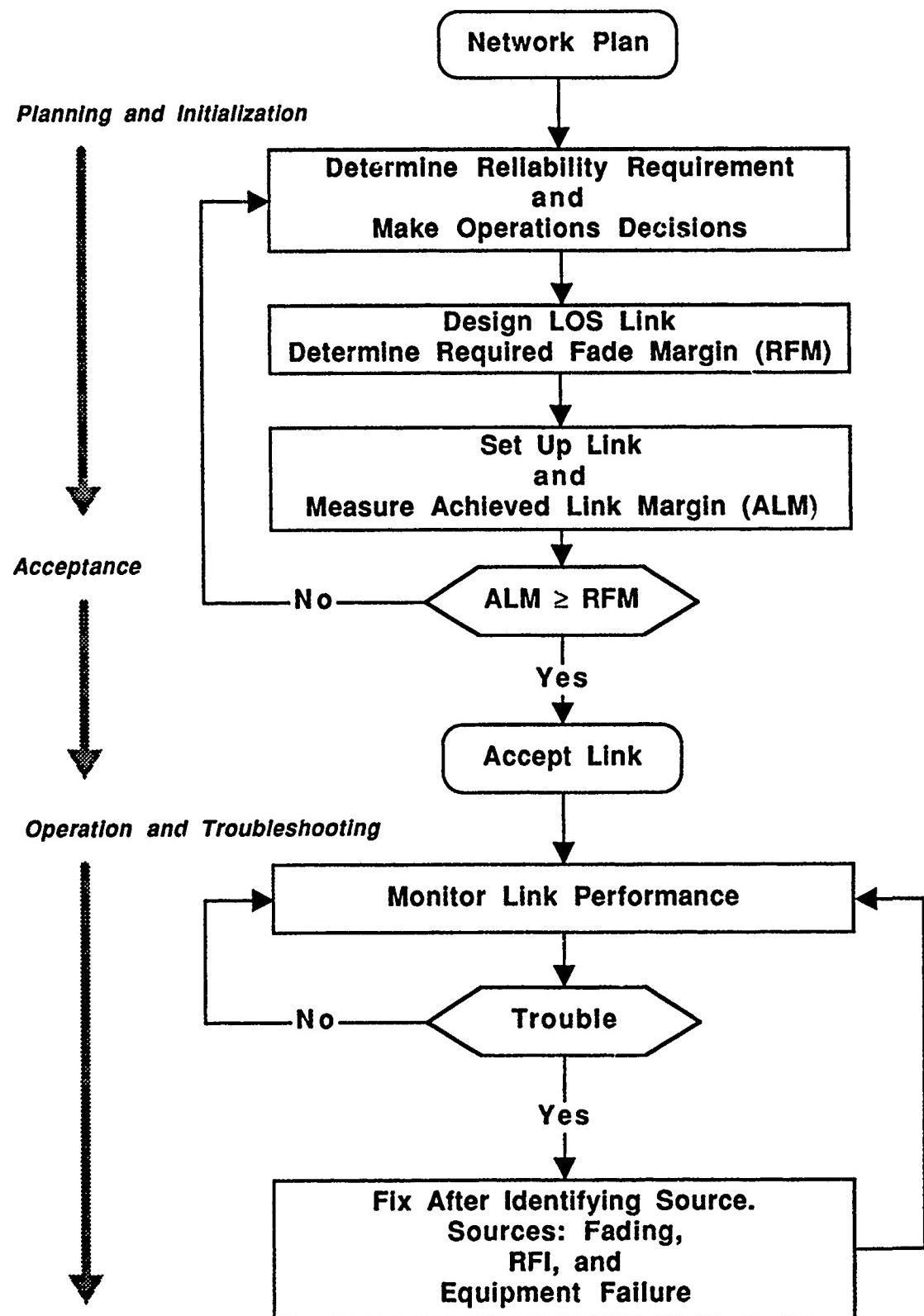
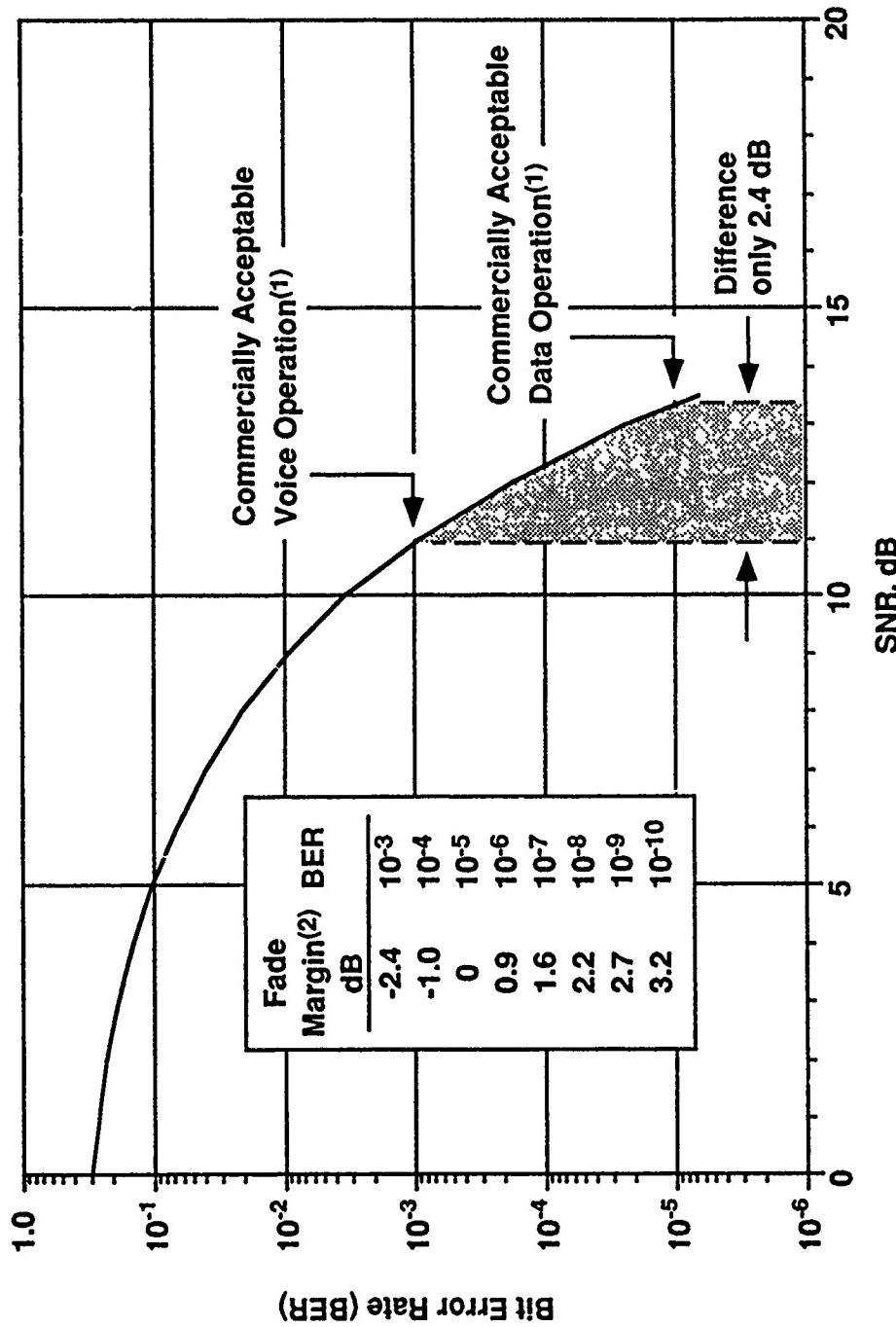


Figure 1-1. General Steps of New Operational Procedures

The AN/GRC-226 radio provides an indication of the level of the RSS incident at the receiver by a "bar" reading on the front panel display of the radio frequency (RF) unit. The number of bars (which varies from 1 to 15) is proportional to the level of the RSS (the more bars, the higher the RSS) and is a relative measurement. The radio indication for a BER of 10^{-5} is approximately 9 bars. For RSS indications of greater than 9 bars, the average value of each additional bar is approximately equivalent to 4 dB. For example, 11 bars would indicate 2 bars of margin (the difference between 11 and 9) equaling approximately 8 dB (2 x 4 dB). However, all margins and calculations in the SCC are done in dB. The enhanced procedures resolve this issue by having the SCC operator perform required calculations in dB, and then convert the results to bars for use by NCS and LOS operators.

The transmission performance of digital radios such as the AN/GRC-226(V) is brittle in that the BER changes rapidly with small changes in the SNR when the SNR is near an operational point at which performance becomes unacceptable. A reliable link design process will provide a safety margin between the normal operating SNR and the acceptable SNR. A safety margin of 8 dB (2 bars) is recommended to account for the ever-present atmospheric-caused changes in RSS or for variations in noise level. Additional margin may be needed to accommodate fading/ high levels of RFI when they are expected to occur. As mentioned earlier, any link margin will also alleviate high-noise conditions when there is no fading.

Current practice is to place the antennas as low as possible, often at or below tree line, consistent with realizing a BER of 10^{-5} without checking and meeting an SNR requirement. This practice is unacceptable because the implemented radio operating point under such conditions is only 2.4 dB from an error rate of 10^{-3} . Error rates larger than 10^{-3} are unacceptable according to commercial practice. This fragility is common to digital radio (see Figure 2-1). This figure illustrates the impact of small dB



Notes:

1. Commercially acceptable operation is assumed to be 10⁻³ BER for digital voice mode and 10⁻⁵ BER for data.
2. This fade margin is in dB relative to acceptable data operation level.

Figure 2-1. Theoretical Non-Coherent Frequency-Shift-Keying Radio Performance

changes on radio BER when the operating point is set at 10^{-5} BER. It is important for the operators to realize that obtaining an RSS that gives a BER of 10^{-5} is not sufficient to ensure satisfactory performance when the inevitable fading occurs. Normal atmospheric changes in the absence of fading cause signal strength changes larger than 2.4 dB over a 24-hour period, particularly in warmer climates.

The maximum fade margins available from the AN/GRC-226(V) radio can be substantial. As illustrated in Figure 2-2, the maximum equipment fade margin is 28 dB for a 40-kilometer (km) link operating at 512 kb/s in Band III. This margin is reduced by RFI or terrain effects when the antennas are placed low. The calculations in the SCC computer only take into account the additional transmission loss caused by terrain.

2.2 MULTIPATH FADING

LOS radio communications can be affected by variations in the RSS caused by atmospheric variations in clear-air refractivity, as described in CECOM-TR-91-3, "Tactical Line-of-Sight Radio Propagation Reliability." The prevalent phenomenon is atmospheric multipath fading, which is caused by destructive interference between two or more superrefracted rays arriving at the receiving antenna by different paths. This produces time-varying fluctuations in the RSS. Reflection multipath fading, which produces less rapid fluctuations, is due to interference between direct and ground-reflected rays (see Figure 2-3). The ability of a link to withstand decreases in the RSS is represented by its fade margin, which is the amount, expressed in dB, by which the normal RSS exceeds that required for 10^{-5} BER operation. Radio outages due to fading phenomena can last from a few seconds to a few hours depending on the actual fade margin of the radio link.

There are other fading phenomena, such as obstruction fading (caused by subrefractive atmospheric effects) and ducting (caused

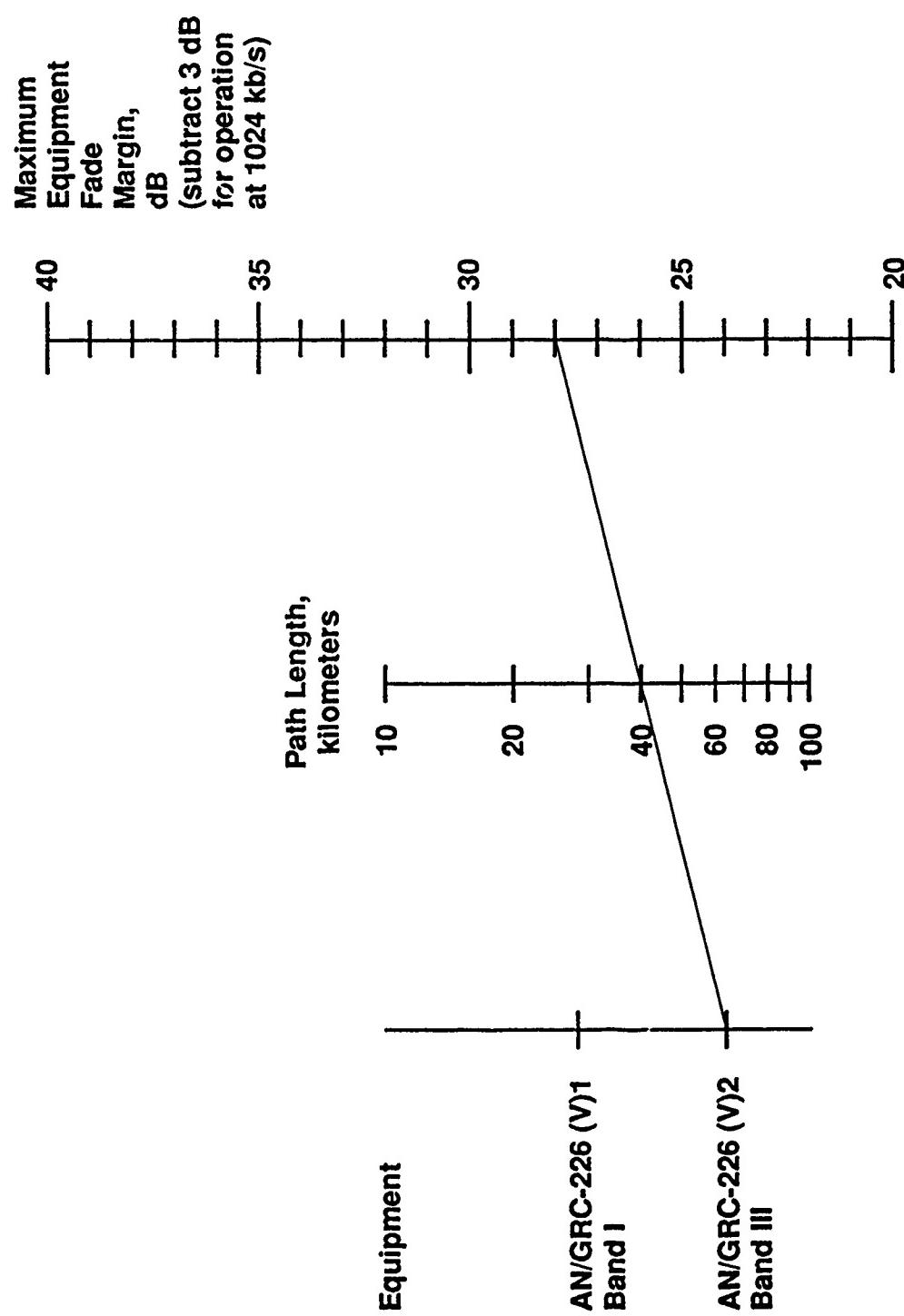


Figure 2-2. Maximum Available Equipment Fade Margin at 256 or 512 kb/s

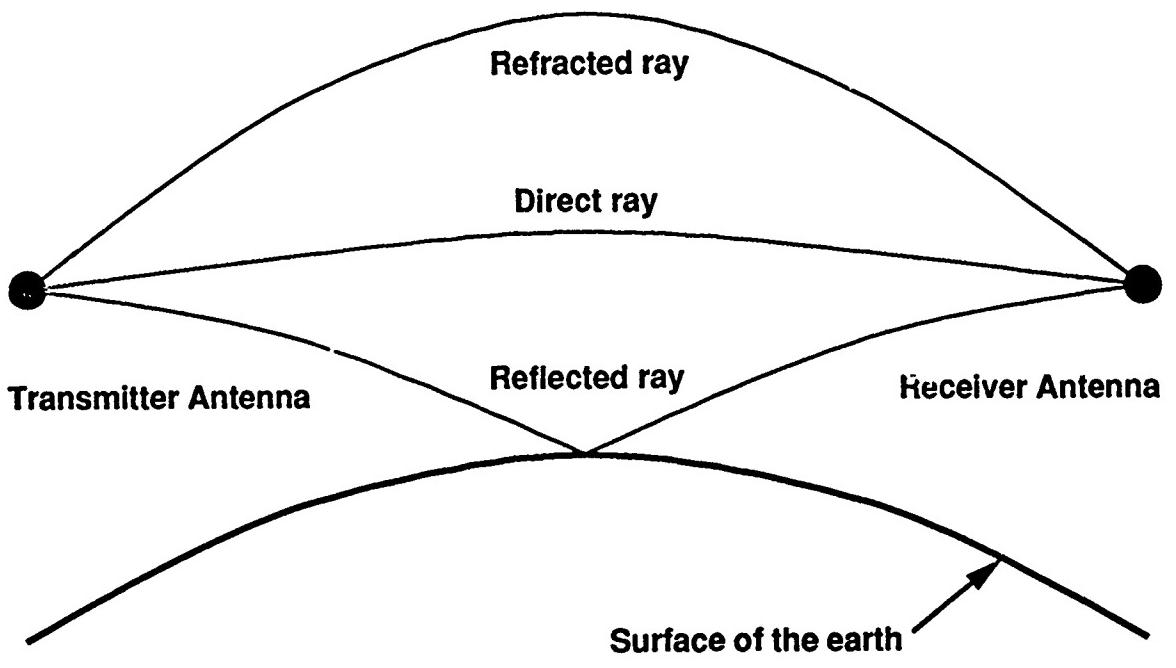


Figure 2-3. Multipath Fading: Destructive Interference of Multiple Rays

by extreme superrefractive effects). These fading phenomena are much less common than multipath fading and are therefore not covered in this document.

Propagation outage due to multipath fading is a function of propagation climate, path length, radio frequency, and fade margin. Some guidelines for the occurrence, time behavior, and impact of multipath fading are:

- o Fading will evidence itself as a time-varying reduction in the number of RSS bars.
- o Fading events can cause trunk encryption devices (TEDs) and other devices to lose synchronization.
- o A fading outage can be misinterpreted as an equipment failure.
- o For a fixed fade margin and link length, fading is about 4.5 times worse in Band III than in Band I.
- o A link of 40 km will have about 12 times as much fading outage as one of 20 km in the same area, operating at the same frequency, and with the same fade margin.
- o Fading effects will be present in both directions of transmission on a link in the same time interval, but, because the transmitting and receiving frequencies are different, not necessarily at the same moment.
- o Fading generally affects other similar links in an area during the same time interval.
- o Multipath fading effects are intermittent with durations of a few seconus to a few hours. Deep fades (greater than 15 dB) normally are of short duration and

shallow fades (less than 15 dB) last for longer periods. Greater fade margins reduce the ... cts of both the number and duration of fades.

- o Multipath fading is most likely to occur ... om a few hours after sunset to a few hours after sunrise on warm, clear, and windless nights.
- o Fading is worse in hot, humid climates than in cool, dry climates.
- o Fading outages are self-healing (i.e., equipment replacement is not the appropriate course of action).

The multipath fading model contained in CECOM-TR-91-3 is shown graphically in simplified form in the nomogram in Figure 2-4. The nomogram is an approximation and is to be used until a computer implementation of the model can be provided. It describes propagation reliability as a function of climate, path length, and radio frequency.

The propagation climate scale in the nomogram in Figure 2-4 describes the following worldwide range of climates:

Good - Propagation climate such as that encountered in the Rocky Mountains in the United States (U.S.) or in cooler regions of Germany, e.g., mostly cool, dry, and with continual mixing of the air.

Average - Propagation climate encountered on the average in most of the Continental U.S. (CONUS), e.g., moderate summertime humidity, heat, and temperature differentials between day and night.

Difficult - Propagation climate such as that encountered in areas of Florida and regions of SWA that are not adjacent to

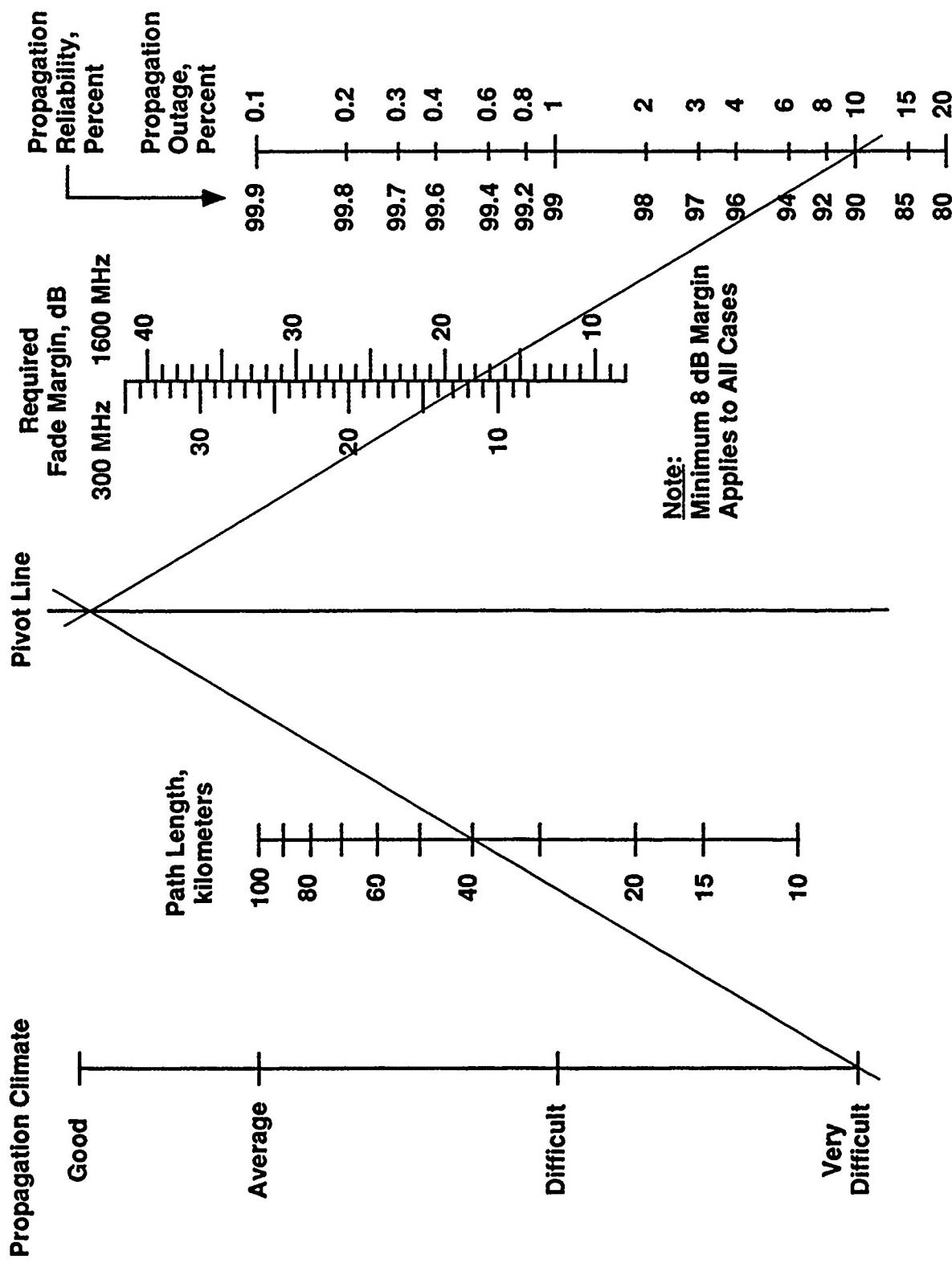


Figure 2-4. Multipath Fading Nomogram

large bodies of water, e.g., high humidity, heat, and temperature differentials between day and night.

Very difficult - Propagation climate such as that encountered in the coastal area of the Persian Gulf, e.g., large temperature differentials between day and night, high heat and humidity, and large variations of these with height above the local terrain.

The general climate categories apply to local warm seasons. Mission duration and weather affect the choice of category that is used for planning purposes. If the link will be operated only during a period of freezing temperatures or in the presence of gale-force winds, the equivalent climate category to be used in planning is "Good".

The application example shown in the nomogram is for a very difficult climate and a path length of 40 km. The user draws a line through these two points to the pivot line. The desired propagation reliability for a nominal design is 90 percent, which represents a 10-percent probability of outage due to propagation. The user draws a second line from the pivot-line intersection to the 90-percent point on the right-hand scale. This line shows that the approximate fade margins required to achieve the 90-percent reliability are 12 dB in Band I (using the center frequency of 300 MHz) and 18 dB in Band III (using the center frequency of 1600 MHz). In general, the known and unknown values in the nomogram can be used in arbitrary combinations, provided that the two lines drawn by the user intersect on the pivot line.

The probability of fading decreases as the path length decreases. Paths shorter than 10 km will have negligible fading, as can be seen from the nomogram. However, short paths are still subject to the minimum fade margin requirement of 8 dB (2 bars) because of possible transmission losses associated with ground reflections.

This nomogram is intended for use by the SCC operator to determine the RFM needed to provide the desired reliability. The nomogram and its use will be described further in section 3.1.

Some of the procedures used to minimize the effects of fading (e.g., good siting, high RSS) could increase exposure to RFI. This needs to be considered when planning for field operation. Generally, any signal strength margin which is engineered into a link to minimize fading is also available to defeat a high noise level from RFI when the link is not experiencing fading.

2.3 RADIO FREQUENCY INTERFERENCE

In general, the capability of a communications system such as the AN/GRC-226(V) radio to provide reliable communication in the presence of noise or noise plus interference is measured by the achievable BER. For a given modulation technique, the BER is a function of the ratio $RSS/(N+I)$, where N is the background noise power and I is the interference noise power at the receiver input. This ratio is a generalized definition of the SNR. Since BER degrades (becomes larger) with a decrease of the ratio $RSS/(N+I)$, it can be seen that BER degrades either due to a loss in signal power, as in the case of fading discussed in section 2.2, or due to an increase in interference noise plus background noise. In the LOS Bands I and III, the background noise portion is due to the thermal noise in the receiver plus the noise sources in the man-made environment (i.e., power lines and electrical generators). If RFI is also present, its power will add to the other noise powers, which further decreases the SNR and increases the BER on the link.

The two types of RFI experienced in the field are: (1) expected interference due to co-located radios in the area (co-site interference) or other users operating in the same frequency band (including overshoot) and (2) unexpected interference due to operation of unidentified transmitters. Both types of interfer-

ence affect the received SNR, and therefore the BER, on the link. Either type of interference, if severe enough, will cause a radio outage or difficulty in establishing a radio link. Proper frequency management techniques can minimize friendly interference, and site planning may help alleviate unexpected interference. In both interference cases, there are procedures which can help the operator: (1) identify the existence of a significant interference condition and (2) alleviate the condition. These are further described in sections 3.2 and 3.3. and in Appendixes B and C.

The following network design criteria should be followed by the SCC operator to minimize the effects of interference:

- o Preassign two or more (if possible) alternative frequencies for both ends of each radio link prior to initial setup in the event that present or future interference sources completely disrupt communications.
- o Utilize both polarizations of the Band I or Band III antennas to the maximum extent to minimize the effects of co-site and other RFI.
- o Point antennas away from the direction of known or potential sources of interference.
- o Try to locate/relocate LOS antennas behind a hill or obstacle to provide shielding against interference without compromising the desired RSS.
- o Use Band III as much as possible. Band III operation is less susceptible to co-site or other RFI because of the relatively narrow beamwidth of the Band III antenna (when compared with the Band I antenna). Also, subur-

band-type man-made noises (i.e., power lines, machinery), negligible in the Band III frequency range, may be significant in Band I.

- o Do not cross LOS path bearings.
- o Separate, as much as possible, adjacent antennas that use the same frequency band at a common site.

Some guidelines that can be used to distinguish between interference and multipath fading follow:

- o Interference will not reduce, but can increase, the number of bars.
- o Interference events can cause TEDs and other devices to lose synchronization.
- o An interference outage can be interpreted as an equipment failure very easily.
- o Interference effects do not necessarily occur in both directions of transmission on a link.
- o Interference effects can be of arbitrary duration (i.e., either constant or intermittent).
- o Interference can occur at any hour.
- o Climate is not a consideration regarding the occurrence of RFI.
- o Interference outages are not self-healing.

2.4 SIMULTANEOUS FADING AND RADIO FREQUENCY INTERFERENCE

Fading and RFI can occur simultaneously. If this is suspected and conditions are favorable for fading (for example, nighttime, humid, no wind), the NCS operator should first focus on establishing the presence of fading and then on RFI.

3 NETWORK OPERATIONAL FUNCTIONS

This section describes the methods used by SCC, NCS, and LOS operators to plan, accept, initialize, and operate a radio link to meet a specified reliability objective when the link is subjected to fading or RFI.

3.1 PLANNING AND ACCEPTANCE

MSE LOS link design requires a propagation reliability of 90 percent or better. Critical single-thread links or links for special high-reliability services need propagation reliability of up to 99.9 percent (see CECOM-TR-91-3). A design for 90-percent reliability makes the link subject to a 10-percent probability of propagation outage. The probability of propagation outage reduces to one tenth of a percent when a high-reliability design of 99.9 percent is implemented.

A key requirement in the planning of a link is the RFM, which is obtained from the fading nomogram in Figure 2-4 for the required propagation reliability. A nominal link margin (NLM) that describes the equipment capabilities of the link, according to the SCC computer, must meet the condition $NLM \geq RFM$. The planning for propagation reliability and the information flow between the SCC and NCS operators are described in Appendix A.

The usefulness of a link can be compromised if it is initialized for a reliability lower than that planned at the SCC. This is one reason why the LOS operator is required to perform measure-

ments during link initialization (the SNR test in section C.2.3 of Appendix C) and to forward this information to the NCS operator, who in turn forwards it to the SCC. At the SCC, the measurements are used to calculate an ALM. The link is acceptable for operation if $ALM \geq RFM$. If not, the propagation reliability must be re-estimated using the ALM (example given in Appendix A, Section A.3.2). This re-estimated reliability then becomes the basis for a final decision at the SCC regarding the acceptability of the link for operation.

3.2 INITIALIZATION

Initialization is a joint activity of the NCS and LOS operators. The NCS operator interacts with the LOS operator to initialize the link and to meet link-parameter requirements (RSS, SNR, and BER). The NCS operator obtains these requirements from the SCC, directs link initialization, directs link troubleshooting as needed, and informs the SCC of link status and actual link parameters. The LOS operator initializes the LOS link, makes measurements, and provides measured data to the NCS operator.

Current LOS setup and initialization procedures are performed utilizing the engineering orderwire (EOW). These procedures cover RSS, the SNR test described in section C.2.3 of Appendix C, and loop test 4 (BER or E level test) described in section C.2.4 of Appendix C.

Observation of LOS link operation in the field by Project Manager (PM) MSE and CECOM personnel indicates that many LOS operators do not utilize all of the current procedures for setup and initialization of LOS links even though they are outlined in the AN/GRC-226(V) Technical Manual (TM) and given in 31D MSE transmission operator training. Operators tend to utilize the RSS verification test, and not the BER and SNR tests. Execution of these tests is required since the results need to be evaluated to determine if: (1) the fade margin requirement has been met and

(2) the noise level at the receiver is low enough to allow reliable communication. The SNR test is critical to determining the noise component of the RSS since the noise power will automatically add to the desired signal power. A high noise (interference) reading may warrant re-engineering of the link. Recommended procedures for NCS and LOS operators are given in Appendixes B and C, respectively.

When setting up the link, the following guidelines should be followed by the operators:

- o Locations near power lines or electrical noise sources should be avoided.
- o Successful LOS communications are dependent upon sufficient obstacle and foliage clearance by the antenna beam to obtain the desired RSS. Locate the radio site as close to the top of the hill as possible consistent with using the hill to provide terrain masking against interference from off-path directions.
- o Reliable communications are dependent upon sufficient link margin (additional signal strength above that required for 10^{-5} BER operation) to counter time-varying signal fading.

3.3 CONTINUED OPERATIONS

The NCS operator manages LOS link troubleshooting after an LOS link becomes operational. Generally, trouble may cause one or more of the radio alarms given in Table 3-1. Possible causes of the fault are also noted in Table 3-1. It is important for all of the operators and other involved personnel to realize that there are fault causes other than equipment failure; otherwise, troubleshooting will be inefficient and likely ineffective.

Table 3-1. Line-of-Sight Radio Alarm Matrix

		LOS AN/TRC-190(V) Equipment			
		AN/GRC-226(V) Radio Alarms			
Fault Cause		Low RSS	Regen OOL	Poor Signal Quality (1)	High BER (2)
Fading		X	X	X	X
RF Interference			X	X	X
Equipment		X	X	X	X
Link Design		X	X	X	X

Notes:

1. Present only during Loop Test 3. Not active during normal operation.
2. Present only during Loop Tests 3, 4, and 5. Not active during normal operation.

Deep fades will bring in all the normal operation alarms cited. Equipment failure will bring in only the alarms that originate in equipment following the failed equipment. The NCS operator managing the troubleshooting should evaluate alarm, weather, and fade margin information to determine whether the trouble source is equipment failure, fading RFI. In the LOS assemblages, a fading condition will appear as a low RSS (reduction in the number of bars) on the AN/GRC-226(V) radio for as long as the fading exists. Before any equipment is replaced, the NCS operator should instruct the LOS operator to first perform testing as described in Appendix C to eliminate fading as a potential cause. The guidelines given in section 2.2, relating to the occurrence and impact of fading, should be utilized when diagnosing a fault.

RFI will not appear as low RSS; other than this, the process outlined in the previous paragraph for fading is applicable. Before any equipment is replaced, the NCS operator should instruct the LOS operator to perform testing as described in Appendix C to eliminate RFI as a potential cause. Strong RFI conditions are characterized by the following:

- Strong RFI will appear as a high RSS with high BER and loss of timing.
- RFI will cause the same activation of alarms as deep fading with the exception of the low RSS alarm. Under high-noise (interference) conditions, the RSS can even increase.
- Unlike a fading condition, interference will normally affect only one end of the link (the end facing the interference source).

- o Unlike fading, RFI will occur at any time of the day and may last for any duration of time.
- o RFI will cause severe degradation in quality of EOW.

The options available to alleviate the interference problem are as follows:

- o Raise the antenna to clear all intervening obstacles on the link and switch to high transmit power.
- o Change to an alternate frequency.
- o Realign the antenna to point away from the interference source, if possible.
- o Relocate the radio site.

Additions to operational procedures to troubleshoot fading and RFI and to provide high-reliability links are described in detail in Appendix B for NCS operators and Appendix C for LOS operators.

**TACTICAL LINE-OF-SIGHT PATH RELIABILITY:
IMPROVED MSE SYSTEM PROCEDURES**

**APPENDIX A
SYSTEM CONTROL CENTER OPERATIONAL PROCEDURES**

CECOM-TR-92-1

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APPENDIX A

SYSTEM CONTROL CENTER OPERATIONAL PROCEDURES

A.1 INTRODUCTION

Line-of-sight (LOS) links in Mobile Subscriber Equipment (MSE) have to provide reliable communications in the presence of fading, which temporarily reduces the received signal strength (RSS). Fading can occur during various conditions, such as when layers form in the atmosphere, e.g., on warm, calm nights. Enhanced procedures are needed to achieve the required values of communications reliability, referred to as propagation reliability, that include the effects of fading. This appendix describes such procedures for the planning of links and the acceptance of links for operation.

A.2 PLANNING OF LINKS

Link planning for propagation reliability translates reliability requirements into link parameter requirements. The planning utilizes the System Control Center (SCC) model of the link and a graphically represented fading model that is provided in this appendix. The steps in the planning process are shown in Figure A-1. The link parameter requirements obtained from the planning process are forwarded to the Node Center Switch (NCS) operator for initialization of the link. Proper planning of link margin for a signal fading environment also enhances performance in an RFI environment since this margin is available when fading is not being experienced.

A.2.1 RELIABILITY REQUIREMENTS

Normal LOS link design needs propagation reliability of 90 percent or better. Critical single-thread links or links for special high-reliability services require high propagation reliabil-

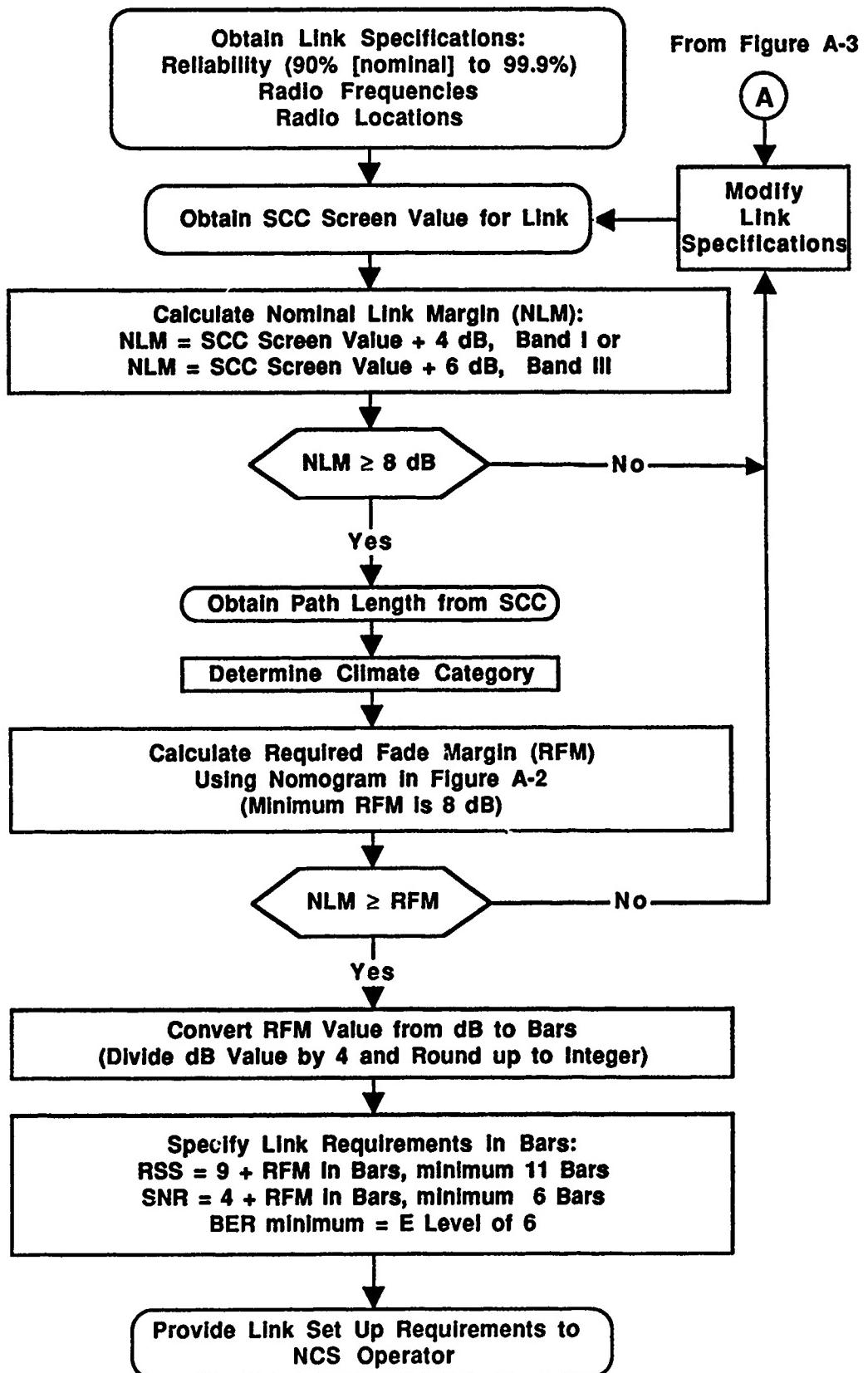


Figure A-1. Link Planning Steps for System Control Center Operators

ity of up to 99.9 percent. However, any reliability value between 90 and 99.9 percent can be chosen. The particular reliability requirement for each link is obtained from the network plan or is specified by the SCC command personnel (S3).

A.2.2 NOMINAL LINK MARGIN

The normal RSS on a link must be larger than the RSS at which the link operates with a bit error rate (BER) of 10^{-5} . The estimated difference in these two signal strengths is the nominal link margin (NLM). The NLM is obtained from the decibel (dB) value displayed on the SCC screen at the completion of the frequency assignment session:

$$\text{NLM} = \text{SCC screen value} + 4 \text{ dB, Band I}$$

$$\text{NLM} = \text{SCC screen value} + 6 \text{ dB, Band III}$$

The 4 dB and 6 dB shown above are part of the SCC software.

A minimum value recommended for the NLM is 8 dB. This provides for signal reductions not related to fading, such as those caused by antenna motion or normal day-to-night atmospheric changes.

A.2.3 REQUIRED FADE MARGIN

A specified value of propagation reliability requires a corresponding minimum difference between the normal RSS and the signal strength at which the link provides a BER of 10^{-5} . This difference is the required fade margin (RFM). The value of the RFM is a function of propagation reliability (specified), radio frequency (assigned), path length (obtained from the SCC), and climate category (discussed below).

General climate categories for worldwide planning of LOS links are:

Good - Propagation climate such as that encountered in the Rocky Mountains in the United States (U.S.) or in cooler regions of Germany, e.g., mostly cool, dry, and with continual mixing of the air.

Average - Propagation climate encountered on the average in most of the Continental U.S. (CONUS), e.g., moderate summertime humidity, heat, and temperature differentials between day and night.

Difficult - Propagation climate such as that encountered in areas of Florida and regions of Southwest Asia that are not adjacent to large bodies of water e.g., high humidity, heat, and temperature differentials between day and night.

Very difficult - Propagation climate such as that encountered in the coastal area of the Persian Gulf, e.g., large temperature differentials between day and night, high heat and humidity, and large variations of these with height above the local terrain.

The general climate categories apply to local warm seasons. Mission duration and weather affect the choice of category that is used for planning purposes. If the link will be operated only during a period of freezing temperatures or in the presence of gale-force winds, the equivalent climate category to be used in planning is "Good".

A key responsibility of the SCC operator is determination of the RFM. The value of the RFM is determined from the nomogram in Figure A-2 by drawing two straight lines, as illustrated in the following example. The climate category in this example is "very difficult", and the path length is 40 km. A line is drawn through these two points to the pivot line. A second line is drawn from the pivot-line intersection to the 90-percent point on the reliability scale. This line shows that the RFM to achieve

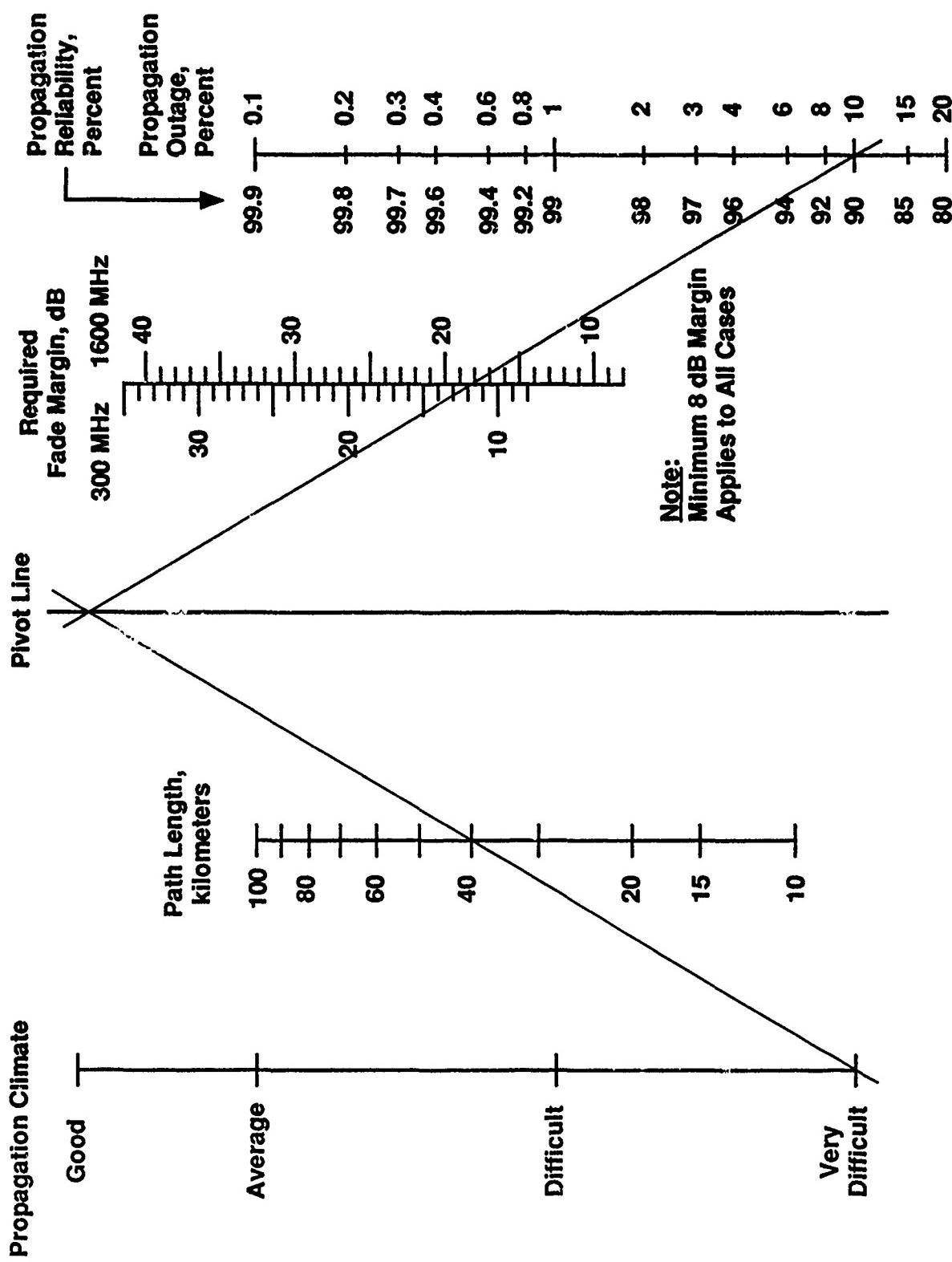


Figure A-2. Multipath Fading Nomogram

90-percent reliability is approximately 18 dB in Band III (using the band center frequency of 1600 MHz). The RFM in Band I would be approximately 12 dB (using band center frequency of 300 MHz).

The probability of fading decreases as the path length decreases. Paths shorter than 10 km will have negligible fading, as can be seen from the nomogram. However, short paths are still subject to the minimum fade margin requirement because of possible transmission losses associated with ground reflections.

The minimum allowed value of the RFM is 8 dB. The reasons for this are the same as those for the minimum value for the NLM. The RFM must be assigned a value of 8 dB when the nomogram indicates an RFM value smaller than 8 dB.

A.2.4 ACCEPTANCE OF LINK PLAN

A plan for a link is acceptable when the planned propagation reliability meets or exceeds the reliability requirement. This is true in the planning stage of the link when:

$$\text{NLM} \geq \text{RFM}.$$

If this condition is not met, the specifications of the link must be changed (radio locations, reliability requirement, or radio frequency).

A.2.5 SPECIFICATIONS FOR SETUP OF LINK

The specifications of the link are forwarded to the NCS operator after the link plan has been accepted. These specifications must be stated in bars to simplify the work of the NCS operator and the LOS operators. To determine the bar value of the RFM, divide the dB value by 4 and round up to an integer. As an example, 18 dB becomes 5 bars.

The link specifications forwarded to the NCS operator are:

- o Reliability category (nominal [90 percent] or high reliability [up to 99.9 percent]).
- o RSS in bars (calculated as 9+RFM bars, with an 11 bar minimum). The 9 bars correspond to 10^{-5} BER operation.
- o Signal-to-noise ratio (SNR) in bars (calculated as 4+RFM bars, with a 6 bar minimum). The 4 bars correspond to 10^{-5} BER operation.
- o BER, expressed as an E level, is a minimum of 6. The BER is not discussed in this appendix, but the LOS operators are required to check the E level.

These specifications cover items that relate to the propagation reliability of the link. There are other specifications, such as radio locations, that are not included in this list.

A.3 ACCEPTANCE OF LINK FOR OPERATION

A link is acceptable for operation when its calculated propagation reliability meets or exceeds the reliability requirement. The calculated propagation reliability for the acceptance of the link for operation is calculated using an achieved link margin (ALM), determined from measurements performed on the link. The steps in the link acceptance process are shown in Figure A-3.

A.3.1 ACHIEVED LINK MARGIN

The ALM is calculated from the SNR, obtained from the NCS operator, that has been measured during initialization of the link:

$$\text{ALM} = \text{SNR} - 4, \text{ bars}$$

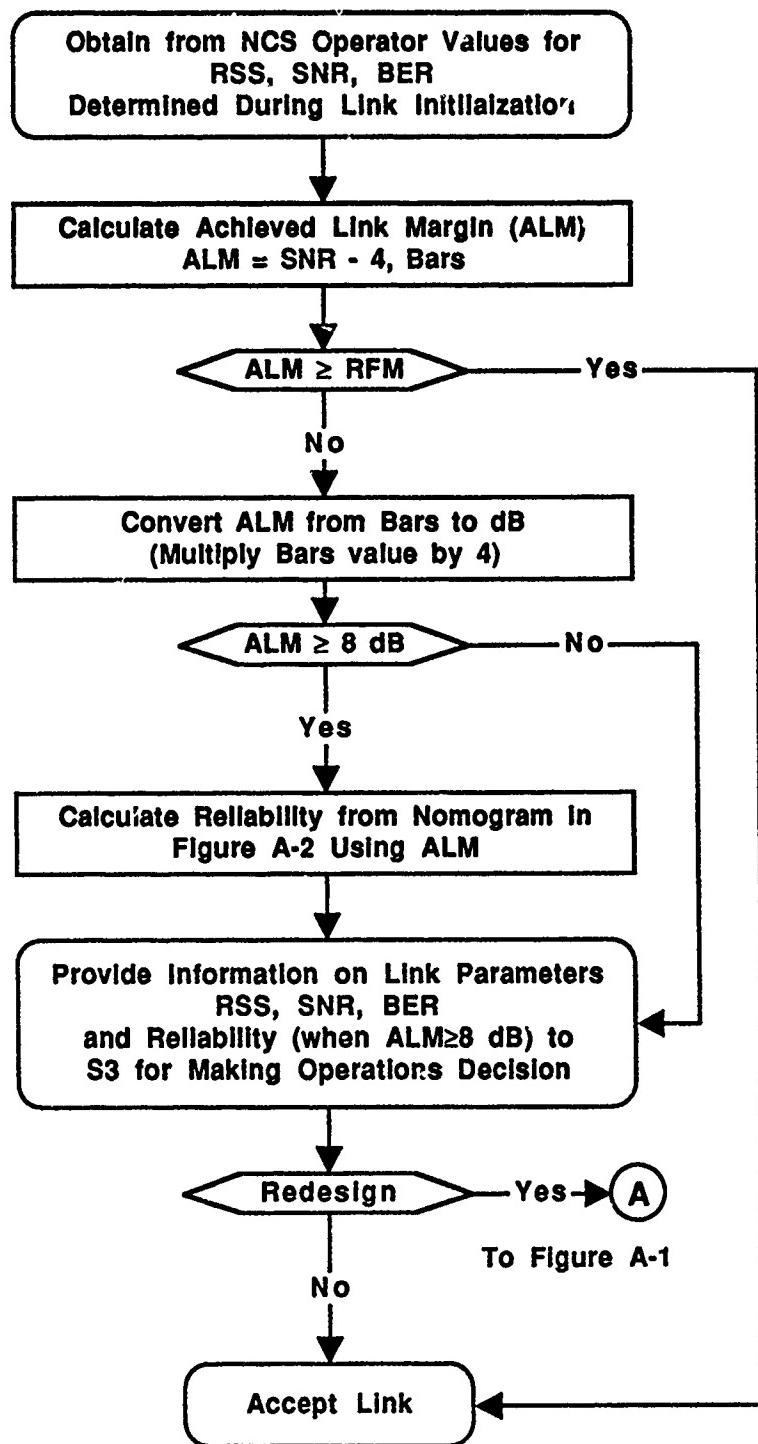


Figure A-3. Link Acceptance Steps for System Control Center Operators

Values of the RSS and the E level should also be obtained from the NCS operator. These are needed in analysis of cases where the ALM is unexpectedly small. The ALM value can differ from the NLM value. One possible reason is high RFI. Another possible reason is use of fixed 15-meter antenna heights in the SCC model that is used to determine the NLM. The terrain loss may be different than that estimated by the SCC software because actual antenna heights differ from 15 meters.

A.3.2 ACCEPTANCE CRITERIA

A link is acceptable for operation when its ALM exceeds or equals the RFM for the link:

$$\text{ALM} \geq \text{RFM, bars}$$

If this condition is not met, a decision to redesign or accept the link must be made by the S3.

As an example, consider the case illustrated in Figure A-4. The plan in this example is to have 99-percent reliability on a 40-km path in a difficult climate. The RFM to achieve this reliability is approximately 18 dB for operation in Band III, from the fade margin scale for 1600 MHz. When measurements are performed, the ALM of the link may be found to be 3 bars. This becomes an ALM of 12 dB, which is obtained by multiplying the number of bars by 4. The value of ALM is 6 dB smaller than the required value. The reliability of this link for a 12-dB fade margin is 96 percent, from the dashed line in Figure A-4. The S3 must decide whether 96-percent reliability (4-percent outage) is acceptable in view of the planned reliability of 99 percent (1-percent outage).

Tactical considerations may dictate acceptance of a link that does not meet the planned reliability. The information provided

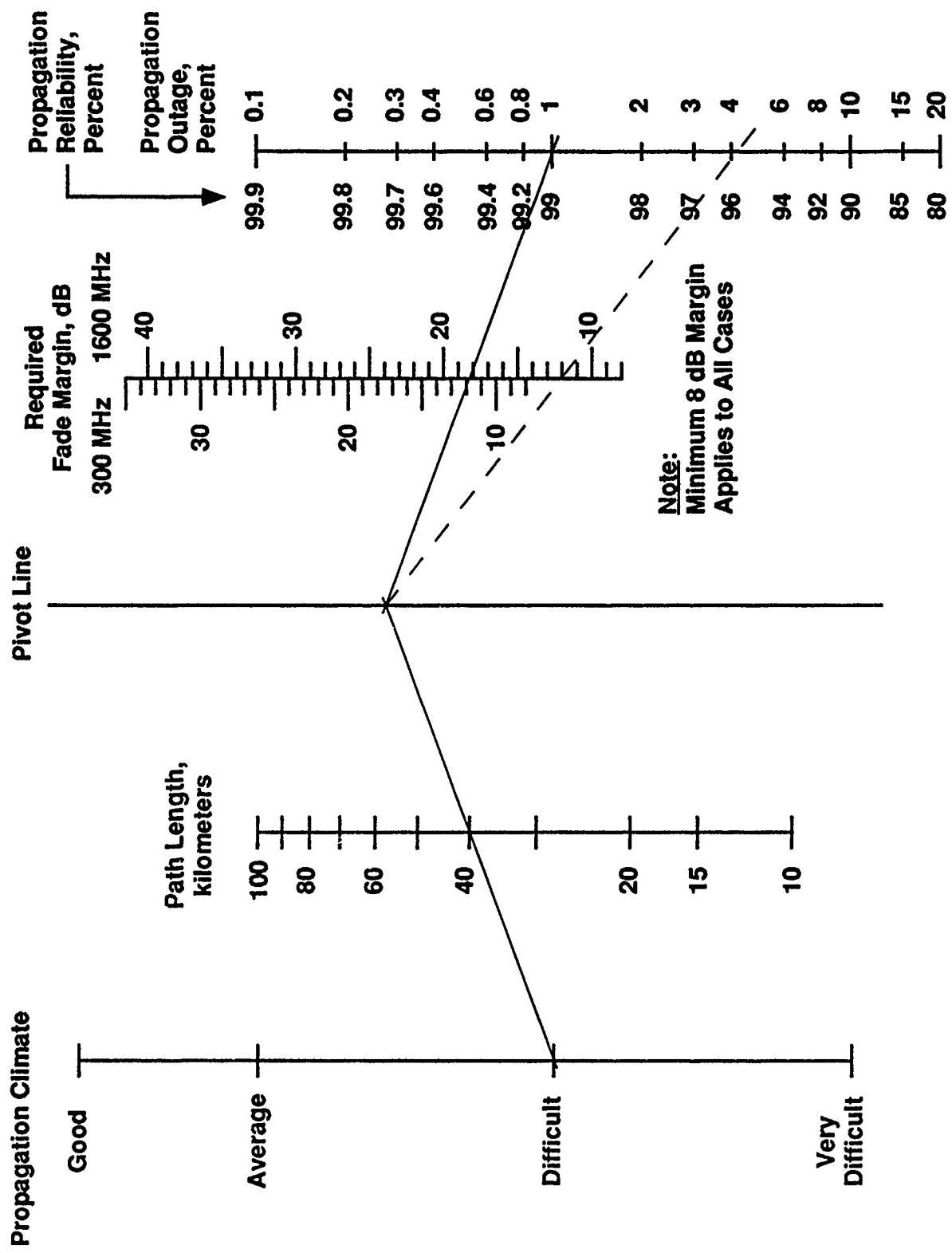


Figure A-4. Application Example

to the S3 in such a case should include the link reliability based on the ALM and the values of the RSS, SNR, and E level obtained during initialization of the link.

A.4 EFFECTS OF RADIO FREQUENCY INTERFERENCE

As discussed in sections A.2 and A.3, obtaining sufficient link fade margin is also dependent on the interference level present at the radio receiver in addition to the strength of the received signal. The interference level is determined by measuring the received signal power at a receiver site with the distant-end transmitter turned off. This procedure is described in the SNR test of section C.3.2 of Appendix C.

The following planning procedures should be followed by the SCC operator to minimize the effects of interference:

- o Two or more (if possible) alternative frequencies should be preassigned for both ends of each radio link prior to initial setup in the event that present or future interference sources completely disrupt communications.
- o Utilize both polarizations of the Band I or Band III antennas to the maximum extent to minimize the effects of co-site and other RFI.
- o Point antennas away from the direction of known or potential sources of interference.
- o Try to locate/relocate LOS antennas behind a hill or obstacle to provide shielding against interference without compromising the desired RSS.
- o Use Band III as much as possible. Band III operation is less susceptible to co-site or RFI because of the

relatively narrow beamwidth of the Band III antenna (when compared with the Band I antenna). Also, suburban-type man-made noises (e.g., power lines, machinery), negligible in the Band III frequency range, may be significant in Band I.

- o LOS path bearings should not cross one another.
- o Adjacent antennas using the same frequency band at a common site should be separated as much as possible.

**IMPROVED LINE-OF-SIGHT PATH RELIABILITY:
IMPROVED MSE SYSTEM PROCEDURES**

**APPENDIX B
NODE CENTER SWITCH OPERATIONAL PROCEDURES**

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APPENDIX B

NODE CENTER SWITCH OPERATIONAL PROCEDURES

B.1 INTRODUCTION

The Node Center Switch (NCS) operator manages LOS link initialization and LOS link troubleshooting after the link becomes operational. These management functions include interacting with the System Control Center (SCC) operator regarding link specifications, directing link initialization and link troubleshooting by the LOS operators, and informing the SCC operator regarding link status. The enhanced procedures presented in this appendix are targeted to improved link reliability and accommodation of the threats of propagation fading and radio frequency interference (RFI).

The NCS operator manages:

- o Initialization of a radio link during initial setup with emphasis on achieving the received signal strength (RSS), signal-to-noise ratio (SNR), and bit error rate (BER, or E level) requirements specified by the SCC operator.
- o Troubleshooting an operational link, i.e., one that has been put into service but which is currently experiencing a continuous or intermittent outage.

Figure B-1 is a process flowchart of the enhanced LOS link initialization and continued operations. Selected material from Appendix C, Line-of-Sight Operational Procedures, is presented in the following sections. It is recommended that the NCS operator become thoroughly familiar with Appendix C.

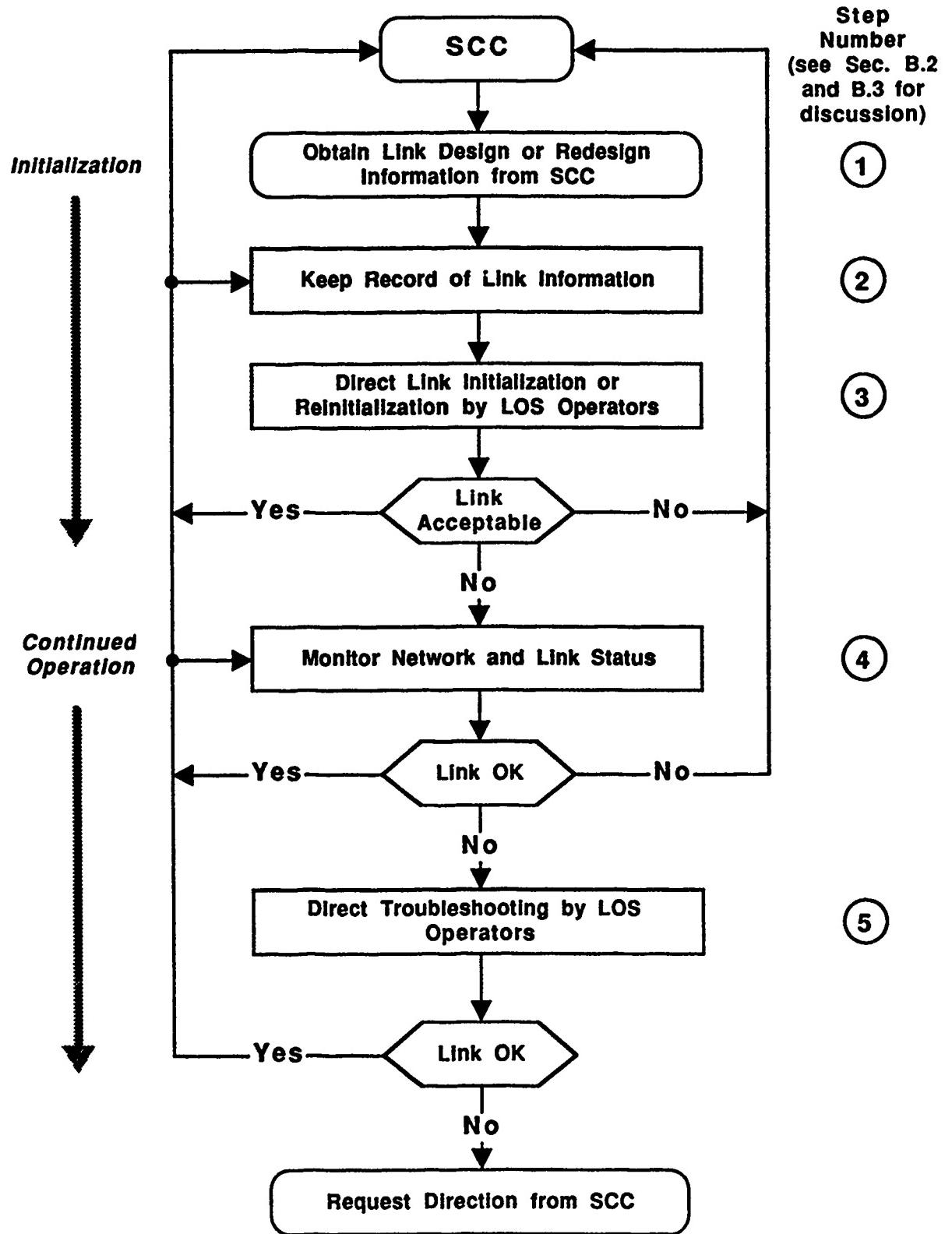


Figure B-1. Line-of-Sight Link Management for Node Center Switch Operators

B.2

LINE-OF-SIGHT LINK INITIALIZATION

The numbered steps of the process outlined in Figure B-1 are detailed in the following material.

Step 1 of the process outlined on Figure B-1 (reference to Figure C-1 will also be helpful) is to obtain the link design requirements from the SCC for the RSS (minimum of 11 bars), SNR (minimum of 6 bars), and the BER (minimum of 10^{-6} , expressed as an E level of 6) and the identification of the link as either nominal reliability (90 percent) or high reliability (up to 99.9-percent reliability).

Step 2 is to record the link design requirements for future reference.

Step 3 is to direct the link initialization by the LOS operators (see Figure C-1). This step depends on whether the link is nominal or high reliability:

- o For nominal reliability, start the initialization of the link with low transmitter power and low antenna heights and increase them only as necessary to meet the RSS, SNR, and BER for nominal reliability requirement. Minimum transmitter power and antenna height is desirable to maximize technical and tactical camouflage.
- o For high reliability, it is presumed that the maximum RSS and SNR are needed. Therefore, start the initialization of the link with high transmitter power and antenna heights that clear all obstacles between the transmitter and the receiver so as to obtain the maximum possible RSS and SNR. This provides the highest available reliability. It may be noted that increasing the power level/antenna height will reduce the technical and tactical camouflage. The decision to perform

this step involves a trade-off which must be determined by the Unit S3. NCS operators will be given the instruction to perform this step by the SCC operator.

This step also includes a decision point for the high reliability setup. The two options for directions to the LOS operators following measurement of the maximum RSS and SNR are: (1) maintain original transmitter power and antenna height and (2) reduce the antenna height/power level to the minimum necessary (SNR of 6 bars). If the latter option is implemented, the antenna height/power level should be returned to their original high-reliability settings whenever fading is observed in the general area.

Also included in this step are reporting and recording the RSS, SNR, and BER test results obtained by the LOS operators. These results are to be recorded and, if met, the acceptability of the link is to be reported to the SCC operator. If any of the requirements (RSS, SNR, or BER) can not be met on a best-effort basis, a redesign, including a new set of requirements, is to be requested from the SCC operator who should consult with the S3 before redesigning the link. The SCC operator may, for tactical reasons, indicate acceptance of the link even though it does not meet the requirements. Otherwise, Steps 2 and 3 are to be repeated using the new set of requirements. It is important that this step be repeated whenever the antenna is readjusted, the antenna height is increased/decreased, or the transmitter power is increased/decreased. This completes link initialization.

B.3 LINE-OF-SIGHT LINK CONTINUED OPERATIONS

Step 4 of the process outlined in Figure B-1 involves monitoring the current link status. Any outages, either continuous or intermittent, should be reported to the SCC operator and the LOS operators.

Step 5 is direction of the link troubleshooting procedure by the LOS operators for a link that is continuously out or is experiencing intermittent changes of state between in and out. It is assumed that sufficient loopback testing has been performed with the Small Extension Node (SEN), Large Extension Node (LEN), and/or NCS assemblages to narrow down the trouble to the LOS radio link. The three basic causes for a continuous or intermittent outage are:

- o Reduction in RSS due to time-varying fading on the link.
- o Increase in link noise due to RFI.
- o Equipment problems (including communications security [COMSEC] mismatch or antenna misalignment).

When troubleshooting, the equipment should not be changed out unless it is unequivocally identified as the trouble source. If there is any uncertainty, fading and RFI are to be eliminated as likely causes before any equipment is replaced. The NCS operator should interrogate alarm information on all links connected to the NCS, weather information (likelihood of fading), and known fade margin information (from records obtained during the initialization phase) when troubleshooting. For example, fading can intermittently affect more than one link at a time. This trait will be helpful in making a fading trouble identification.

B.3.1 TROUBLE IDENTIFICATION

The purpose of troubleshooting is identification of the trouble source. Generally, trouble triggers one of the radio alarms shown in Table B-1. Possible fault causes are also noted in Table B-1. It is important for the operators to realize that alarms also indicate fault causes other than equipment failure.

Table B-1. Line-of-Sight Radio Alarm Matrix

		LOS AN/TRC-190(V) Equipment			
		AN/GRC-226(V) Radio Alarms			
Fault Cause		Low RSS	Regen OOL	Poor Signal Quality (1)	High BER (2)
Fading		X	X	X	X
RF Interference			X	X	X
Equipment		X	X	X	X
Link Design		X	X	X	X

Notes:

1. Present only during Loop Test 3. Not active during normal operation.
2. Present only during Loop Tests 3, 4, and 5. Not active during normal operation.

However, distinguishing between equipment-related trouble (e.g., improper antenna alignment or module failures) and multipath fading may be difficult due to similarities in alarm conditions.

The radio alarms important in identifying fading and RFI are: RSS, high BER, regenerator out-of-lock (OOL), and poor signal quality.

The above-mentioned alarms will also be present in equipment failures. Therefore, it is important to verify proper equipment operation by checking for higher priority equipment faults, COMSEC mismatches, and proper antenna alignment. The next step is to investigate fading and RFI as likely trouble sources. The difference between fading and RFI will be mainly differentiated by the low RSS fault on the AN/GRC-226(V). In a signal fading condition, the RSS will be either low or fluctuating. In an RFI environment, there will be a high RSS with the transmitters turned off. If the RSS has not changed much from that measured during initialization (difference of a bar or less), equipment is the most likely trouble source.

The guidelines given in section B.3.2 for fading, in section B.3.3 for RFI, and in section B.3.4 for equipment problems should be helpful in diagnosing and troubleshooting.

B.3.2 OPERATION IN A SIGNAL FADING ENVIRONMENT

LOS radio communications can be affected by variations in RSS caused by atmospheric layering. The prevalent phenomenon is atmospheric multipath, which is caused by destructive interference between two or more rays arriving at the receiving antenna by different paths through the atmosphere and producing time-varying fluctuations in the received signal level. Reflection multipath, which produces less rapid fluctuations, is due to interference between direct and ground-reflected rays. The ability of a link to withstand these decreases in RSS is repre-

sented by its fade margin, i.e., the amount in dB by which the normal RSS exceeds that required for 10^{-5} BER operation. Radio outages due to fading phenomena can last from a few seconds to a few hours, depending on the available fade margin for the radio link.

Some guidelines for the occurrence, time behavior, and impact of multipath fading are:

- o Fading will evidence itself as a time-varying reduction in the number of RSS bars.
- o Fading events can cause trunk encryption devices (TEDs) and other devices to lose synchronization
- o A fading outage can be misinterpreted as an equipment failure very easily.
- o For a fixed fade margin and link length, fading is about 4.5 times worse in Band III than in Band I.
- o A link of 40 km will have about 12 times as much outage as one of 20 km in the same area, operating at the same frequency and with the same fade margin.
- o Fading effects will occur in both directions of transmission on a link in the same time interval, but, because the transmitting and receiving frequencies are different, not necessarily at the same moment.
- o Fading generally affects other similar links in an area during the same time period.
- o Multipath fading effects are intermittent with durations of a few seconds to a few hours. Deep fades normally are of short duration, and shallow fades are

longer. Larger fade margins reduce both the number and duration of fades.

- o Multipath fading is most likely to occur on warm, clear, and still nights in the time between a few hours after sunset to a few hours after sunrise.
- o Fading is much worse in hot and humid climates than in cool and dry climates.
- o Fading outages are self-healing (equipment replacement is not necessary or effective).

The options to alleviate the fading problem are to:

- o Switch to high transmitter power (do so immediately for a high-reliability link).
- o Wait until the problem corrects itself. This may take a few minutes up to several hours.
- o Raise the antennas until they clear all intervening obstacles in the path.

Selection of one or more of the above options should be directed by the NCS operator to the LOS operator.

B.3.3 OPERATION IN A HIGH RADIO FREQUENCY INTERFERENCE ENVIRONMENT

In general, the capability of a communications system such as the AN/GRC-226 radio to provide reliable communication in the presence of noise or noise plus interference is measured by the achievable bit error rate (BER). For a given modulation technique, the BER is a function of the ratio $RSS/(N+I)$, where N is the background noise power and I is the interference noise power

at the receiver input. This ratio is a generalized definition of the SNR. Since BER degrades (becomes larger) with a decrease in the ratio RSS/(N+I), it can be seen that BER degrades either due to a loss in signal power, as in the case of fading, or an increase in interference noise plus background noise. In the ultra high frequency (UHF) LOS Bands I and III, the background noise portion is due to the thermal noise in the receiver and the noise sources in the man-made environment (i.e., ambient noise, power lines, generators). If interference is also present, its signal power will add to the noise power, thereby decreasing the SNR and increasing the BER on the link.

The two types of RFI experienced in the field are: (1) expected interference due to known co-located radios in the area (co-site interference) or other users operating in the same frequency band (including overshoot) and (2) unexpected interference due to operation of unidentified transmitters. Both types of interference affect the received SNR, and therefore the BER, on the link. Either type of interference, if severe enough, will cause a radio outage or difficulty in establishing a radio link. Proper frequency management techniques can minimize friendly interference, and site planning may help alleviate unexpected interference. In both interference cases, therefore, there are procedures that can: (1) help identify the existence of a significant interference condition and (2) identify what can be done to try to alleviate the condition.

Normally, radio outages caused by strong interference will be characterized by adequate (or high) RSS level indications on the baseband unit as opposed to a fading condition which will cause a low RSS indication (see Table B-1), loss of timing causing the regenerator OOL alarm to activate, and noticeable interference/distortion on the AN/GRC-226(V) engineering orderwire (EOW).

NOTE: Even though the received EOW signal from the distant radio site may be completely distorted, one-way orderwire transmission may still be effective in the other direction if the distant

receiver is not simultaneously interfered with. (This is usually the case since RFI is most effective when received through the mainbeam, and possibly the sidelobes, of the receive antenna.) This feature of the AN/GRC-226(V) may be used to advantage in coordinating frequency changes, site relocation, etc., as discussed in subsequent procedures.

The effects of interference signals on the radio receiver are very dependent on the characteristics of the interference. These effects can range from a distorted EOW signal (in the EOW mode) to bursty type errors or a total loss of data transmission (in the DATA mode).

Some guidelines for distinguishing between RFI and multipath fading follow:

- o Interference will not reduce, but can increase, the number of bars.
- o Interference events can cause TEDs and other devices to lose synchronization.
- o An interference outage can be interpreted as an equipment failure very easily.
- o Interference effects do not necessarily occur in both directions of transmission on a link.
- o Interference effects can be of arbitrary duration (i.e., either constant or intermittent).
- o Interference can occur at any hour.
- o Climate is not a consideration regarding the occurrence of RFI.
- o Interference outages are not self-healing.

The options available to alleviate the interference problem are as follows:

- (1) Raise the antenna to clear all intervening obstacles on the link and switch to high transmit power.
- (2) Change to an alternative frequency.
- (3) Realign the antenna to point away from the interference source, if possible.
- (4) Relocate the radio site.

B.3.4 EQUIPMENT PROBLEMS

Equipment problems, including incorrect antenna operation and alignment of antennas (including proper guying of masts), should be the first potential problem area to be investigated once a link problem has been identified to be LOS related. The LOS operator should follow procedures as outlined in the Technical Manual (TM) for the AN/GRC-226(V) (TM 11-5820-1029-13&P) to troubleshoot the LOS link problem. If the trouble source is not obviously equipment failure, however, fading and RFI should be investigated as likely trouble sources.

**TACTICAL LINE-OF-SIGHT PATH RELIABILITY:
IMPROVED MSE SYSTEM PROCEDURES**

**APPENDIX C
LINE-OF-SIGHT OPERATIONAL PROCEDURES**

CECOM-TR-92-1

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APPENDIX C

LOS OPERATIONAL PROCEDURES

C.1 LINE-OF-SIGHT OPERATION OVERVIEW

Normal operation of the ultra high frequency (UHF) radio set, the AN/GRC-226(V), involves the transmitting and receiving of voice, data, and facsimile information between two locations. Current line-of-sight (LOS) link initialization and continued operations involve:

- o Setup of the AN/TRC-190(V) shelter at a location specified by the SCC.
- o Initialization of LOS links using procedures outlined in the technical manuals (TMs). LOS links are generally initialized with radios in the low power mode and antennas at tree line to maximize technical and tactical camouflage.
- o Monitoring of continued operation, reporting of any problem encountered to the Node Center Switch (NCS) operator, and troubleshooting as directed by the NCS operator.

The enhanced procedures in this appendix provide improved link reliability and accommodate fading and RFI. They include a procedure for setting up and initializing the link to meet received signal strength (RSS) and signal-to-noise ratio (SNR) requirements derived from the link reliability requirement and provided by the NCS/System Control Center (SCC) operators. An optional procedure provides the maximum RSS and SNR to meet a high-reliability requirement and compensate for the anticipated effects of fading or RFI. This may require an increase in antenna height/transmitted power level to maximize the link RSS and the SNR.

Figure C-1 is a process flowchart of the enhanced LOS link initialization and continued operations. The step numbers in the circles refer to the steps discussed in the following material.

Step 1 of the process is to install and set up the AN/TRC-190(V) assemblage as outlined in the technical manual, TM 11-5820-1023-13&P.

Step 2 is to obtain and record the requirements from the NCS operator for the RSS, SNR, and the bit error rate (BER, or E level) and the identification of the link as either nominal reliability or high reliability .

Step 3 is to initialize the link using the test procedures outlined in section C.2 of this appendix. This step depends on whether the link is nominal or high reliability:

- o For nominal reliability, start the initialization of the link with low transmitter power and low antenna heights and increase them only as necessary to meet the RSS, SNR, and BER for nominal reliability requirement. Minimum transmitter power and antenna height is desirable to maximize technical and tactical camouflage.
- o For high reliability, start the initialization of the link with high transmitter power and antenna heights that clear all obstacles between the transmitter and the receiver so as to obtain the maximum possible RSS and SNR. This provides the highest available reliability. It may be noted that increasing the power level/antenna height will reduce the technical and tactical camouflage. The decision to perform this step involves a trade-off which must be determined by the Unit S3. LOS operators will be given the instruction to perform this step by the NCS operator.

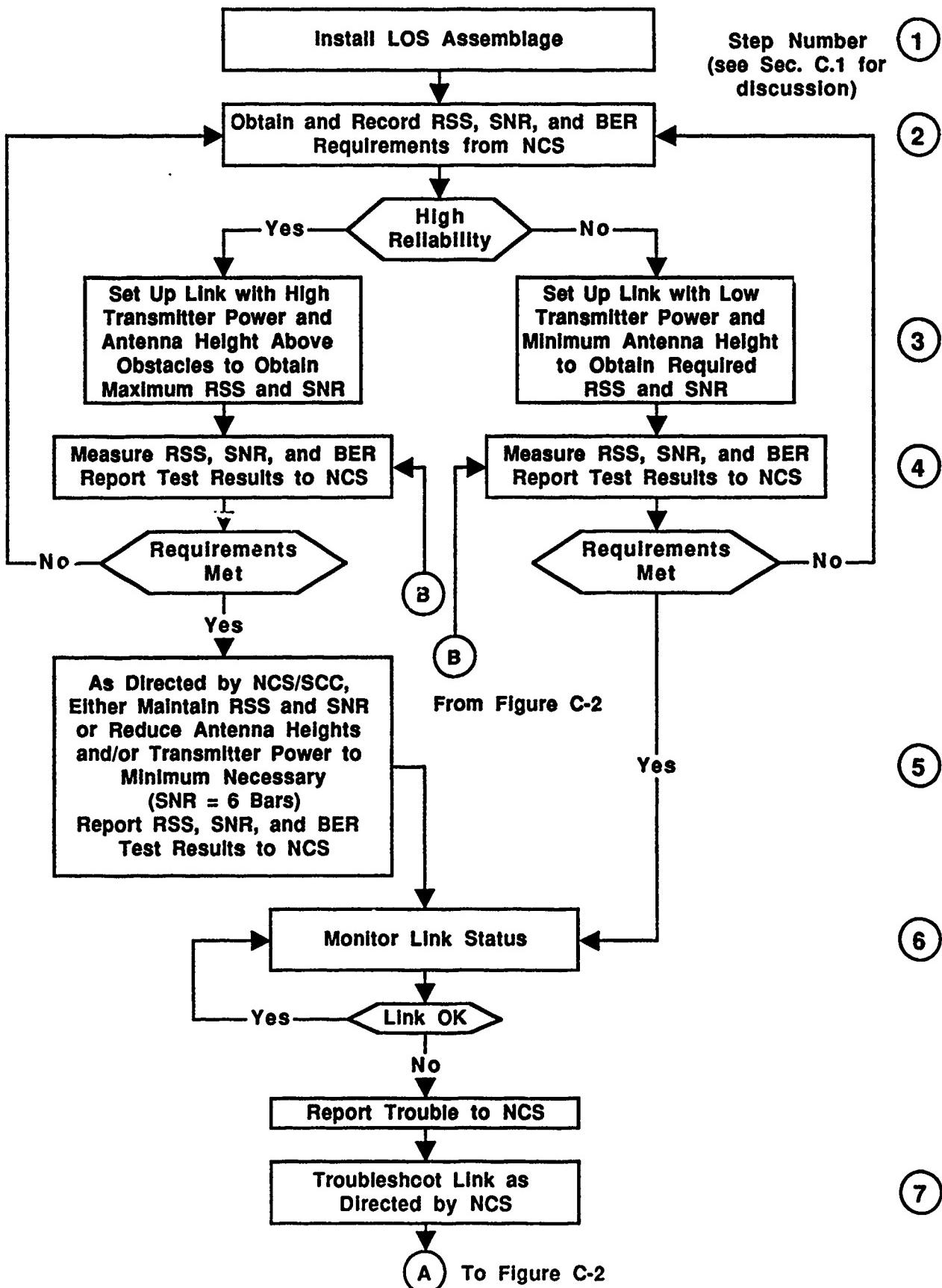


Figure C-1. Link Initialization and Continued Operation Process for Line-of-Sight Radio Operators

Step 4 is to measure the RSS, SNR, and BER (E level; also see sections C.2.2, C.2.3, and C.2.4) and to report the test results to the NCS operator. If any of the requirements (RSS, SNR, or BER) are not met, Step 3 should be repeated with suitable changes in the operating conditions as directed by the NCS operator. It is important that this step be repeated whenever the antenna is readjusted, the antenna height is increased/decreased, or the transmitter power is increased/decreased.

Step 5 in the process is a decision point for the high-reliability setup. The two options are: (1) maintain current transmitter power and antenna height or (2) reduce the antenna height/power level as directed by the NCS operator to the minimum necessary (SNR = 6 bars) and report test results for the new operating conditions to the NCS operator.

Step 6 involves monitoring current link status. Any outages, either continuous or intermittent, should be reported to the NCS operator.

Step 7 is the link troubleshooting, which is interactive with the NCS operator, for a link which is continuously out or is experiencing intermittent changes of state between in and out. The procedures in section C.3 of this appendix should be used in troubleshooting problem links. The first part of this process, as outlined on Figure C-2, calls for determining whether the problem source is fading, RFI, or equipment failure. The LOS operator will then be instructed to increase the transmitted power level, correct the antenna alignment/increase antenna height to overcome the effects of fading or RFI. Problems diagnosed as equipment problems should be rectified. After the trouble is fixed, the RSS, SNR, and BER should be remeasured and rerecorded. The LOS operator should then continue to monitor the link status.

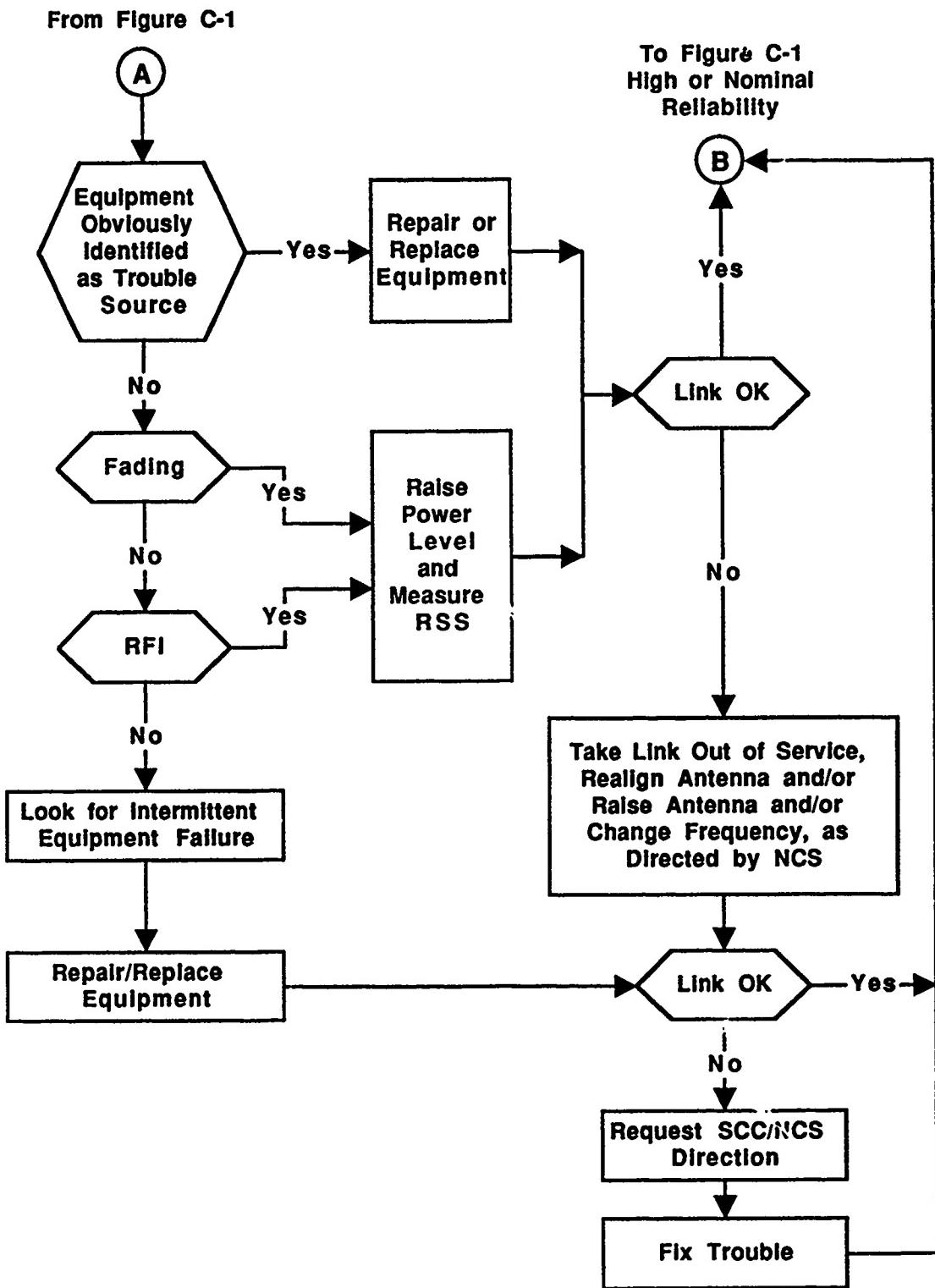


Figure C-2. Link Troubleshooting Procedures for Line-of-Sight Radio Operators

C.2

LINE-OF-SIGHT LINK SETUP AND INITIALIZATION

This section provides the RSS, SNR and BER (E level) test procedures for the LOS link setup and initialization process listed in section C.1 of this appendix. These test procedures are to be used as needed in executing the section C.1 process. Some information contained herein has been replicated from the AN/GRC-226(V) TM and has been combined with the new procedural information. The test procedures provided require knowledge of and reference to the AN/TRC-190(V) and AN/GRC-226(V) TMs, TM 11-5820-1023-13&P and TM 11-5820-1029-13&P, respectively.

C.2.1

ENGINEERING ORDERWIRE FACILITY

The engineering orderwire (EOW) facility is used to align the antenna subassemblies and in performing the RSS, SNR, and BER tests before normal operations begin. It is available only between the operators of the two UHF radio sets on a single link when the UHF radio sets are not carrying traffic. EOW is available both with and without tone. EOW without tone (0-5-0) allows voice coordination between the local and distant ends. EOW with tone (0-6-0) gives an audible (tone) means to supplement the visual (bars) means to measure signal strength when aligning the antennas. Establish EOW communications as follows:

- Local UHF radio set. Call distant UHF radio set operator (0-5-0). Ask distant UHF radio set operator to silence alert tone by pressing any key on the keypad, and to call local UHF radio set operator.
- Distant UHF radio set. Call local UHF radio set operator (0-5-0). The incoming call causes alert tone to sound in headphone and loudspeaker and CALLED to appear on display. Press any key to silence alert tone. Two operators can now talk to each other.

NOTE: It is imperative that the operator perform each of the following: RSS test, SNR test, and BER (E level) test (loop test 4). RSS alone will not guarantee a reliable link.

C.2.2 RECEIVED SIGNAL STRENGTH

After EOW communications (0-5-0) have been established, it is necessary to verify that the RSS at each UHF radio set is sufficient to meet the requirement obtained from the NCS operator. Verify received signal strength as follows:

- o In the EOW mode (0-5-0), the operators should coordinate for a certain period of time, i.e., several minutes to perform the following RSS measurements.
- o Local UHF radio set. Select EOW plus tone (0-6-0). Check that tone is heard and that display shows required number of horizontal bars with an 11 bar minimum.
- o Distant UHF radio set. The distant operator should check the display for required RSS with an 11 bar minimum. If insufficient, realign antenna subassembly.

NOTE: If realignment does not increase the received signal strength sufficiently, improvements might be made by increasing mast height or relocating the mast.

- o Local UHF radio set. Cancel engineering tone by pressing any key on keypad. Ask distant UHF radio set operator to transmit engineering order wire plus tone (0-6-0).
- o Local UHF radio set. Check for required received signal strength with an 11 bar minimum. If insufficient, realign antenna subassembly.

NOTE: If realignment does not increase the received signal strength sufficiently, improvements might be made by increasing mast height or relocating the mast.

- Local UHF radio set. Ask distant UHF radio set operator to cancel engineering tone by pressing any key on keypad.

C.2.3 SIGNAL-TO-NOISE RATIO TEST

This mandatory test procedure is vital to determining that the reliability of the link will meet requirements and that the noise level at the radio receiver is not sufficient to cause high BER. Proceed as follows:

- Ensure that both antennas are aligned to the proper bearings.
- Ensure that both radios have been configured properly.
- In the EOW mode, the operators should coordinate to disable both transmitters for a certain period of time, i.e., 30-60 seconds to measure the background noise level
- Disable transmitter power on both radios by entering 4-0-4 on their respective front-panel keypads.
- Observe RSS bar readout on front panel by entering 9R on the keypad. Record RSS.
 - If the bar readout on front panel of both radios is more than 8, request a new frequency assignment and repeat procedures. (See section C.3.3 for troubleshooting procedures.)

- If bar readout on front panel of both radios is less than 8, record the number of bars. Power up both transmitters to previous power setting by entering either 4-1-4 (low) or 4-2-4 (high) on the front panel keypads.
- o With the transmitters powered, the bar display on each radio should show an RSS of 6 or more bars above the readout recorded in the previous step, with a minimum of 11 bars.

C.2.4 BIT ERROR RATE (LOOP TEST 4)

Perform the following mandatory loop test procedures to verify satisfactory communication of data, represented by BER or E level, between the distant and local UHF radio sets:

- o In the EOW mode (0-5-0), the operators should coordinate for a certain period of time, i.e., 30-60 seconds to measure the BER.
- o Local UHF radio set. Call distant UHF radio set operator. Ask operator to press key 6, then key 4, then key 6 on keypad to select loop test 4.
- o Local UHF radio set. Select loop test 4 by pressing key 6, then key 4, then key 6 on keypad. Check display. It should indicate L4 --- Ey, where y is at least 6.

NOTE: This indicates that a pattern has been transmitted from the local UHF radio set to the distant UHF radio set and that a pattern has been transmitted to the local UHF radio set from the distant UHF radio set. There should be an error rate better than 1 bit in 10^6 . While in this mode, faults can be interrogated as in the AN/GRC-226 TM, paragraph 3-11.8. RSS (paragraph 3-11.9) can also be interrogated.

- o Distant UHF radio set. Operator should report that display indicates L4 --- Ey, where y is 6.

NOTE: Once the LOS link has been set up and initialized using the procedures outlined in paragraphs C.2.2, C.2.3, and C.2.4, any change in operating parameters (e.g., antenna height to increase/decrease tactical and technical camouflage, antenna bearings, transmitter power, etc.) should be followed by repeating the LOS link initialization procedures to ensure that parameters essential for proper operation have not been degraded.

C.3 CONTINUED LINE-OF-SIGHT OPERATIONS

Once LOS links are initialized, LOS link reliability requires monitoring LOS link status and reporting problems to the local switch operator. Potential LOS link problems may be caused by several sources. These are:

- o Operation in a signal-fading environment.
- o Operation in the presence of RFI.
- o Equipment problems (including communications security [COMSEC] mismatch and antenna misalignment).

When troubleshooting, the equipment is not to be changed out unless it is unequivocally identified as the trouble source. If there is any uncertainty, fading and RFI are to be eliminated as likely causes before any equipment is replaced.

C.3.1 **TROUBLE IDENTIFICATION AND TROUBLESHOOTING PROCEDURES**

The first step in troubleshooting is identification of the trouble source. Generally a trouble or fault brings in one of the radio or modem alarms given in Table C-1. Possible causes of the fault are also noted in Table C-1. It is important for the operators and other involved personnel to realize that there are

Table C-1. Line-of-Sight Radio Alarm Matrix

	LOS AN/TRC-190(V) Equipment			
	AN/GRC-226(V) Radio Alarms			
Fault Cause	Low RSS	Regen OOL	Poor Signal Quality (1)	High BER (2)
Fading	X	X	X	X
RF Interference		X	X	X
Equipment	X	X	X	X
Link Design	X	X	X	X

Notes:

1. Present only during Loop Test 3. Not active during normal operation.
2. Present only during Loop Tests 3, 4, and 5. Not active during normal operation.

fault causes other than equipment failure. However, distinguishing between equipment-related trouble (e.g., improper antenna alignment [including proper guying of masts] or electrical problems) and multipath fading may be difficult due to similarities in alarm conditions. The radio alarms important in identifying fading and RFI are: RSS, high BER, regenerator out-of-lock (OOL), and poor signal quality.

The above-mentioned alarms will also be present in equipment failures. Therefore, it is important to verify proper equipment operation by checking for higher priority equipment faults, COMSEC mismatches, proper antenna alignment, and mast guying. The next step is to investigate fading and RFI as likely trouble sources. The difference between fading and RFI will be mainly differentiated by the low RSS fault on the AN/GRC-226(V). In a signal fading condition, the RSS will be either low or fluctuating. With RFI, there will be a high RSS with the transmitters turned off (see section C.2.3 on the SNR test). If the RSS has not changed much from that measured during initialization (difference of a bar or less), equipment is the most likely trouble source.

The guidelines given in section C.3.2 for fading, in section C.3.3 for RFI, and in section C.3.4 for equipment problems should be helpful in diagnosing and troubleshooting.

C.3.2 OPERATION IN A SIGNAL FADING ENVIRONMENT

LOS radio communications can be affected by variations in RSS caused by atmospheric layering. The prevalent phenomenon is atmospheric multipath, which is caused by destructive interference between two or more rays arriving at the receiving antenna by different paths through the atmosphere and producing time-varying fluctuations in the received signal level. Reflection multipath, which produces less rapid fluctuations, is due to interference between direct and ground-reflected rays. The

ability of a link to withstand these decreases in RSS is represented by its fade margin, i.e., the amount, in dB, by which normal RSS exceeds that required for 10^{-5} BER operation. Radio outages due to fading phenomena can last from a few seconds to a few hours, depending on the available fade margin for the radio link.

Some guidelines for the occurrence, time behavior, and impact of multipath fading are:

- o Fading will evidence itself as a time-varying reduction in the number of RSS bars.
- o Fading events can cause trunk encryption devices (TEDs) and other devices to lose synchronization.
- o A fading outage can be misinterpreted as an equipment failure very easily.
- o For a fixed fade margin and link length, fading is about 4.5 times worse in Band III than in Band I.
- o A link of 40 km will have about 12 times as much outage as one of 20 km in the same area, operating at the same frequency, and with the same fade margin.
- o Fading effects will occur in both directions of transmission on a link in the same time interval, but, because the transmitting and receiving frequencies are different, not necessarily at the same moment.
- o Fading generally affects other similar links in an area during the same time period.

- o Multipath fading effects are intermittent with durations of a few seconds to a few hours. Deep fades normally are of short duration and shallow fades are longer. Larger fade margins reduce both the number and duration of fades.
- o Multipath fading is most likely to occur on warm, clear, and still nights in the time between a few hours after sunset to a few hours after sunrise.
- o Fading is much worse in hot and humid climates than in cool and dry climates.
- o Fading outages are self-healing (equipment replacement is not necessary or effective).

The options to alleviate the fading problem are to:

- o Switch to high transmitter power (do so immediately for a high reliability link).
- o Wait until the problem corrects itself. This may take from a few minutes up to several hours.
- o Raise the antennas until they clear all intervening obstacles in the path.

Selection of one or more of the above options should be directed to the LOS operator from the NCS operator.

C.3.3 OPERATION IN A HIGH RADIO FREQUENCY INTERFERENCE ENVIRONMENT

In general, the capability of the AN/GRC-226(V) radio to provide reliable communication in the presence of noise or noise plus interference is measured by the SNR and the BER or E level tests.

Noise and interference will limit the useful operating range of the radio equipment.

The two types of RFI experienced in the field are: (1) expected interference due to co-located radios in the area (co-site interference) or other users operating in the same frequency band (including overshoot) and (2) unexpected interference due to operation of unidentified transmitters. Both types of interference affect the received SNR, and therefore the BER, on the link. Either type of interference, if severe enough, will cause a radio outage or difficulty in establishing a radio link. Proper frequency management techniques can minimize friendly interference, and site planning may help alleviate unexpected interference. In both interference cases, therefore, there are procedures which can (1) help identify the existence of a significant interference condition and (2) identify what can be done to try to alleviate the condition.

Normally, radio outages caused by strong interference will be characterized by adequate (or high) RSS indications on the baseband unit, as opposed to a fading condition which will cause a low RSS indication (see Table C-1), loss of timing causing the regenerator OOL alarm to activate, and noticeable interference/distortion on the AN/GRC-226 engineering orderwire (EOW).

NOTE: Even though the received EOW signal from the distant radio site may be completely distorted, one-way orderwire transmission may still be effective in the other direction if the distant receiver is not simultaneously subject to high levels of RFI. (This is usually the case since RFI is most effective when received through the mainbeam, and possibly the sidelobes, of the receive antenna.) This feature of the AN/GRC-226 may be used to advantage in coordinating frequency changes, site relocation, etc., as discussed in subsequent procedures.

Some guidelines for distinguishing between RFI and multipath fading follow:

- o Interference will not reduce, but can increase, the number of bars.
- o Interference events can cause TEDs and other devices to lose synchronization.
- o An interference outage can be interpreted as an equipment failure very easily.
- o Interference effects do not necessarily occur in both directions of transmission on a link.
- o Interference effects can be of arbitrary duration (i.e., either constant or intermittent).
- o Interference can occur at any hour.
- o Climate is not a consideration regarding the occurrence of RFI.
- o Interference outages are not self-healing.

The options available to alleviate an RFI problem are as follows:

- (1) Raise the antenna to clear all intervening obstacles on the link and switch to high transmit power.
- (2) Change to an alternative frequency.
- (3) Realign the antenna to point away from interference source, if possible.
- (4) Relocate the radio site.

C.3.4 EQUIPMENT PROBLEMS

Equipment problems, including incorrect antenna operation and alignment of antennas, should be the first potential problem area to be investigated once the LOS operator has been notified that a link problem has been identified as LOS related. The LOS operator should follow procedures as outlined in the TM for the AN/GRC-226(V), TM 11-5820-1029-13&P, to troubleshoot the LOS link problem. If the trouble source is not obviously equipment failure, however, fading and RFI should be investigated as likely trouble sources.

APPENDIX D

LIST OF ACRONYMS

LIST OF ACRONYMS

ALM	Achieved Link Margin
BER	Bit Error Rate
CECOM	Communications-Electronics Command
COMSEC	Communications Security
CONUS	Continental United States
CW	Continuous Wave
EOW	Engineering Orderwire
FSK	Frequency-Shift Keying
LEN	Large Extension Node
LOS	Line-of-Sight
MSE	Mobile Subscriber Equipment
NCS	Node Center Switch
NLM	Nominal Link Margin
OOL	Out-of-Lock
PM	Project Manager
RF	Radio Frequency
RFI	Radio Frequency Interference
RFM	Required Fade Margin
RSS	Received Signal Strength
SCC	System Control Center
SEN	Small Extension Node
SNR	Signal-to-Noise Ratio
SWA	Southwest Asia
TED	Trunk Encryption Device
TM	Technical Manual
UHF	Ultra High Frequency